

NEMOSHIP



Co-funded by
the European Union
GA No. 101096324

DECARBONISATION OF MARITIME TRANSPORT WITH LARGE BATTERY SYSTEMS

January 29th 2026



cidetec
energy storage

Corvus Energy

elkon

equinor

In Extenso
INNOVATION CROISSANCE

THONANT

SDI

SIEMENS

SOLSTAD OFFSHORE

VUB VRIJE
UNIVERSITEIT
BRUSSEL



- Your microphones will be muted during the event
- We will have Q&A sessions
- You can ask your questions in the Question box at anytime during the event (see bottom right of the screen)
- You can also vote for questions asked by others
- Slides will be shared on our website:
<https://nemoship.eu/results/>

Questions

12

Naomi Vous
How do you create an account?
Use the 'Signup' button on the top right of the screen.

0

James
What's the weather today?

Sondages

Are you interested in this new feature?

Yes

No

Soumettre le vote

il y a plus de 7 ans

Do you want to receive our newsletter?

68% Yes

32% No

il y a plus de 7 ans

Liens Sondages Questions Chat

Liens Sondages Questions Chat



9:00 to 9:15 - **Welcome and NEMOSHIP introduction** (CEA)

9:15 to 9:50 - **Keynote presentation on safety of batteries** (CEA) and Q&A

9:50 to 10:20 - **Marine batteries safety and characterisation** (Corvus / Cidetec) and Q&A

Coffee break - 10:20 to 10:35

10:35 to 11:10 - **Innovation 1: Heterogeneous battery systems and dedicated control** (CEA / Solstad / Elkon)

- Sizing a heterogeneous battery system to fit the vessel needs
- Control solution developed for increased BESS lifetime (BPMS – Battery Power Management System)
- Battery system installation on Normand Drott vessel
- Q&A

11:10 to 11:45 - **Innovation 2: NEMOSHIP Digital Platform for optimal battery operations** (Siemens / Ponant)

- Overview of the platform capabilities
- Preliminary feedback following deployment on Le Commandant Charcot vessel
- Q&A

11:45 to 12:15 - **Applicability to full electric use cases** (SDI / Elkon) and Q&A

12:15 to 12:30 - **Closing**



NEMOSHIP

NEMOSHIP INTRODUCTION

Solène Goy, CEA



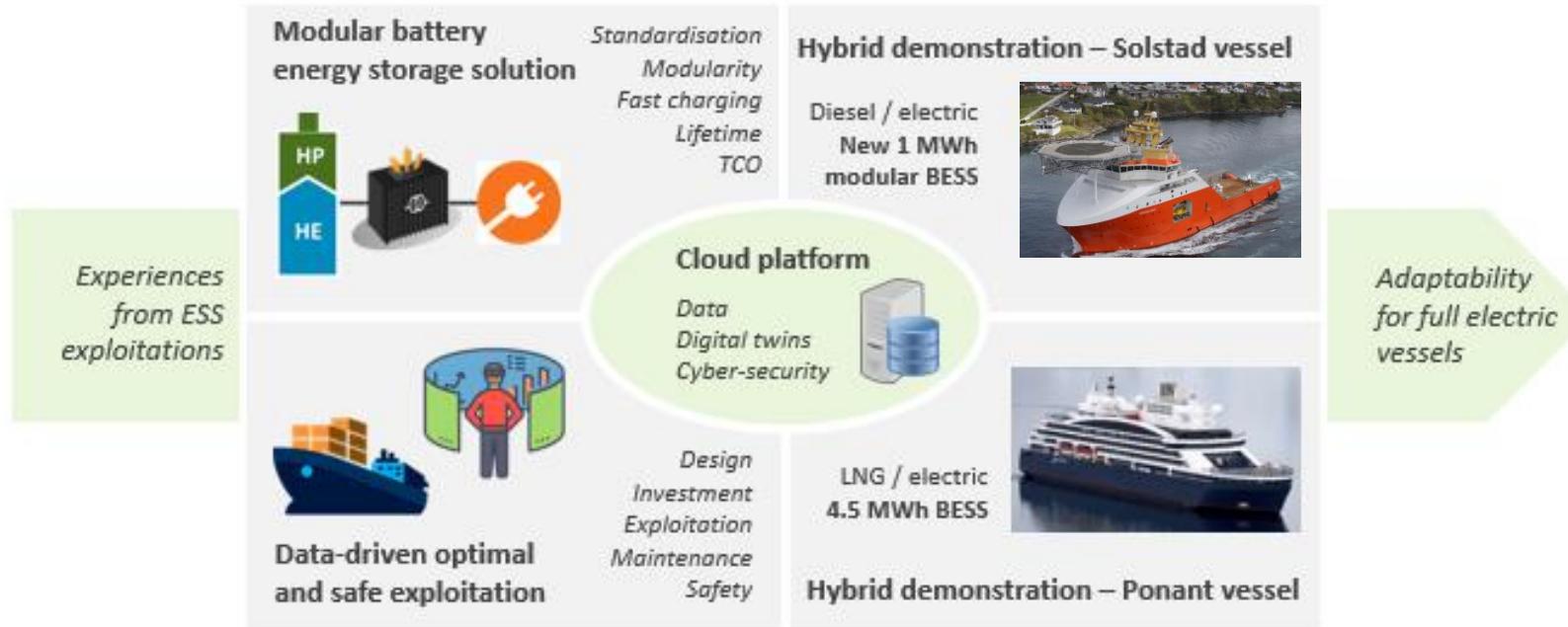
NEMOSHIP

| | |
|-----------------|---|
| Title | NEw MOdular electrical architecture & digital platform to optimise large battery systems on SHIPs |
| Call ID | HORIZON-CL5-2022-D5-01-01 - Exploiting electrical energy storage systems and better optimising large battery electric power within fully battery electric and hybrid ships (ZEWT Partnership) |
| Type | Innovation Action |
| Lead | CEA |
| Duration | 4 years - 01/01/2023 to 31/12/2026 |
| Total cost | 11.3 M Euros |
| EU contribution | 7.9 M Euros |

PROJECT EXPECTED OUTCOMES



NEMOSHIP



2 main innovative solutions:

- A modular and standardised battery energy storage solution enabling to exploit different types of batteries (HE and HP)
- A cloud-based digital platform enabling a data-driven optimal and safe exploitation

HE: High-Energy

Optimized for sustained energy delivery, suitable for longer voyages and continuous operation.

HP: High-Power

Designed for rapid discharge and charge cycles, ideal for dynamic marine applications.

PROJECT EXPECTED OUTCOMES

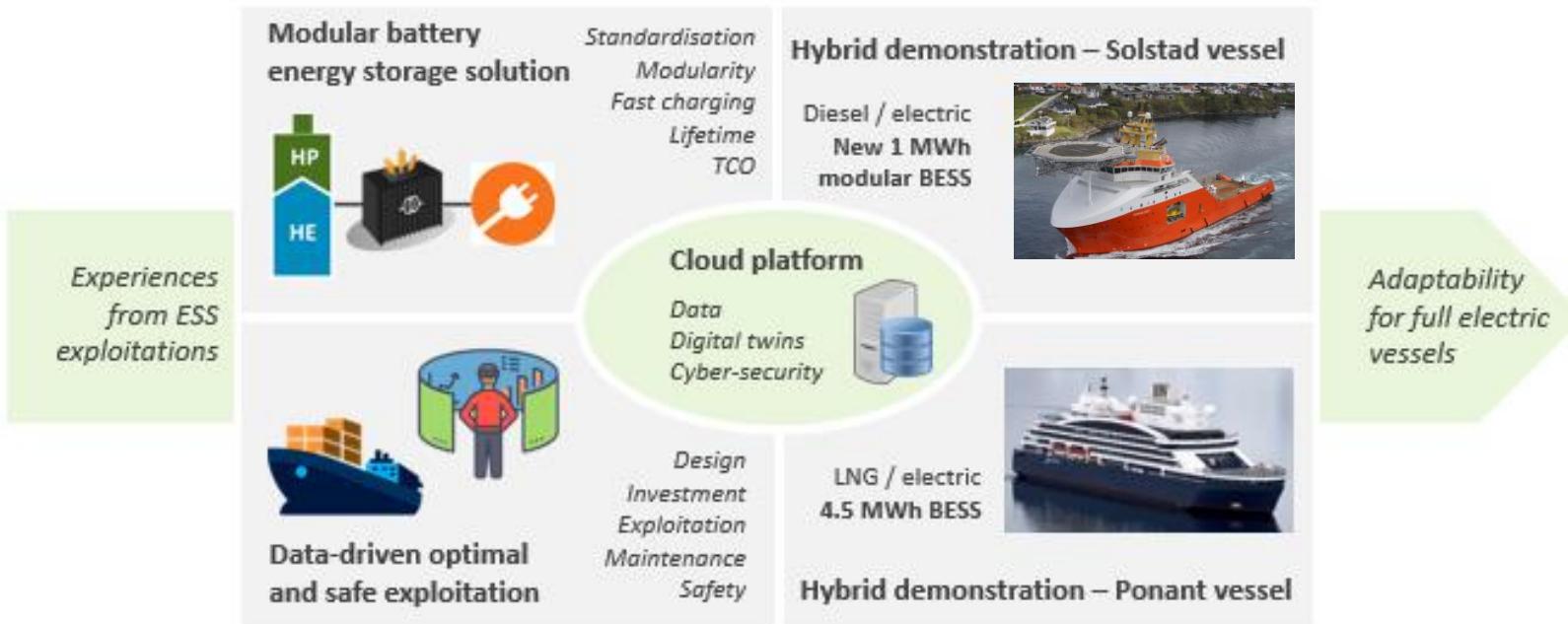


NEMOSHIP

2 main innovative solutions:

- A modular and standardised battery energy storage solution enabling to exploit different types of batteries (HE and HP)
- A cloud-based digital platform enabling a data-driven optimal and safe exploitation

→ Demonstrate their maturity for hybrid ships at TRL 7 and their adaptability for full-electric ships

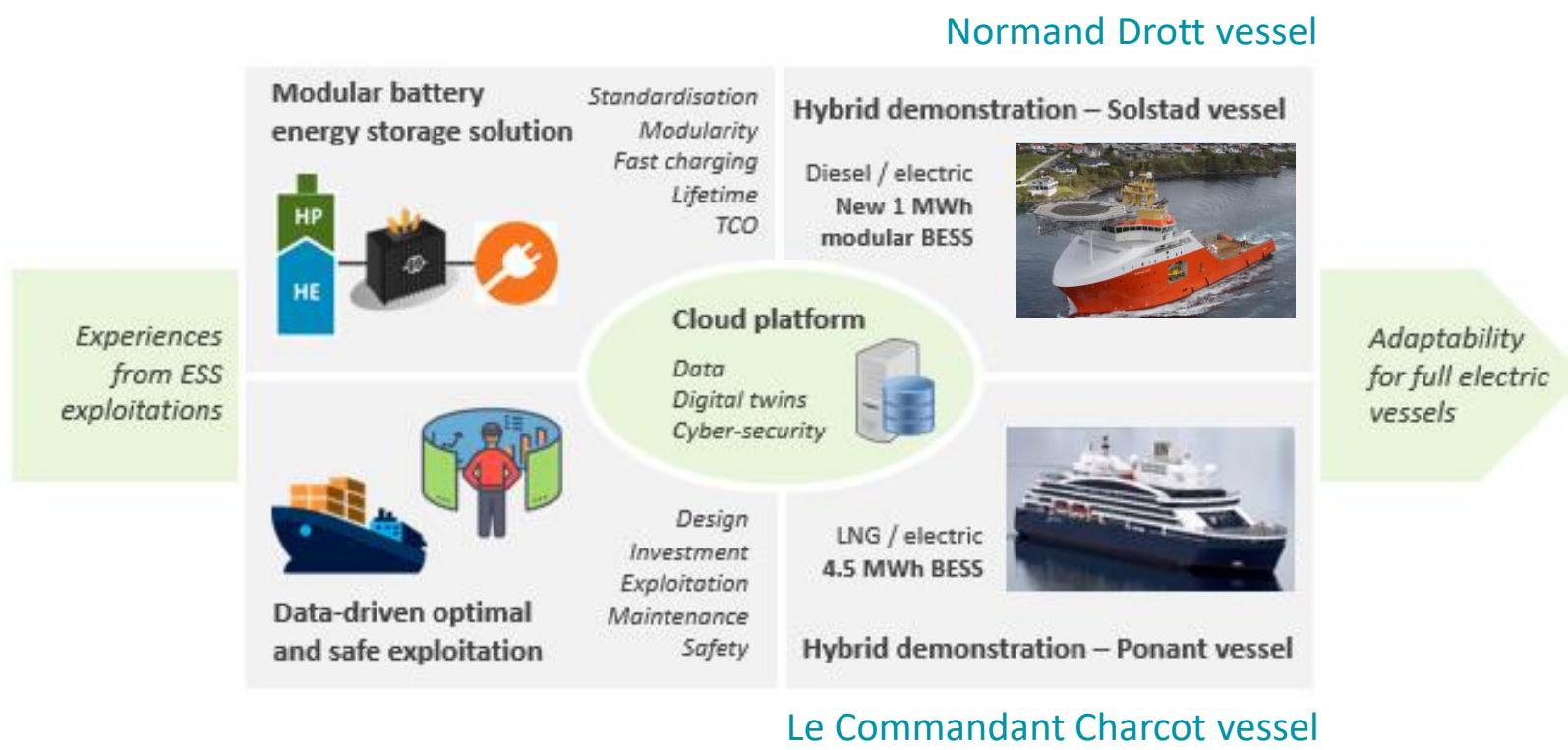


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PROJECT EXPECTED OUTCOMES



NEMOSHIP



2 main innovative solutions:

- A modular and standardised 1.1 MWh battery energy storage solution enabling to exploit different types of batteries (HE and HP)
- A cloud-based digital platform enabling a data-driven optimal and safe exploitation

→ Demonstrate their maturity for hybrid ships at TRL 7 and their adaptability for full-electric ships



Co-funded by
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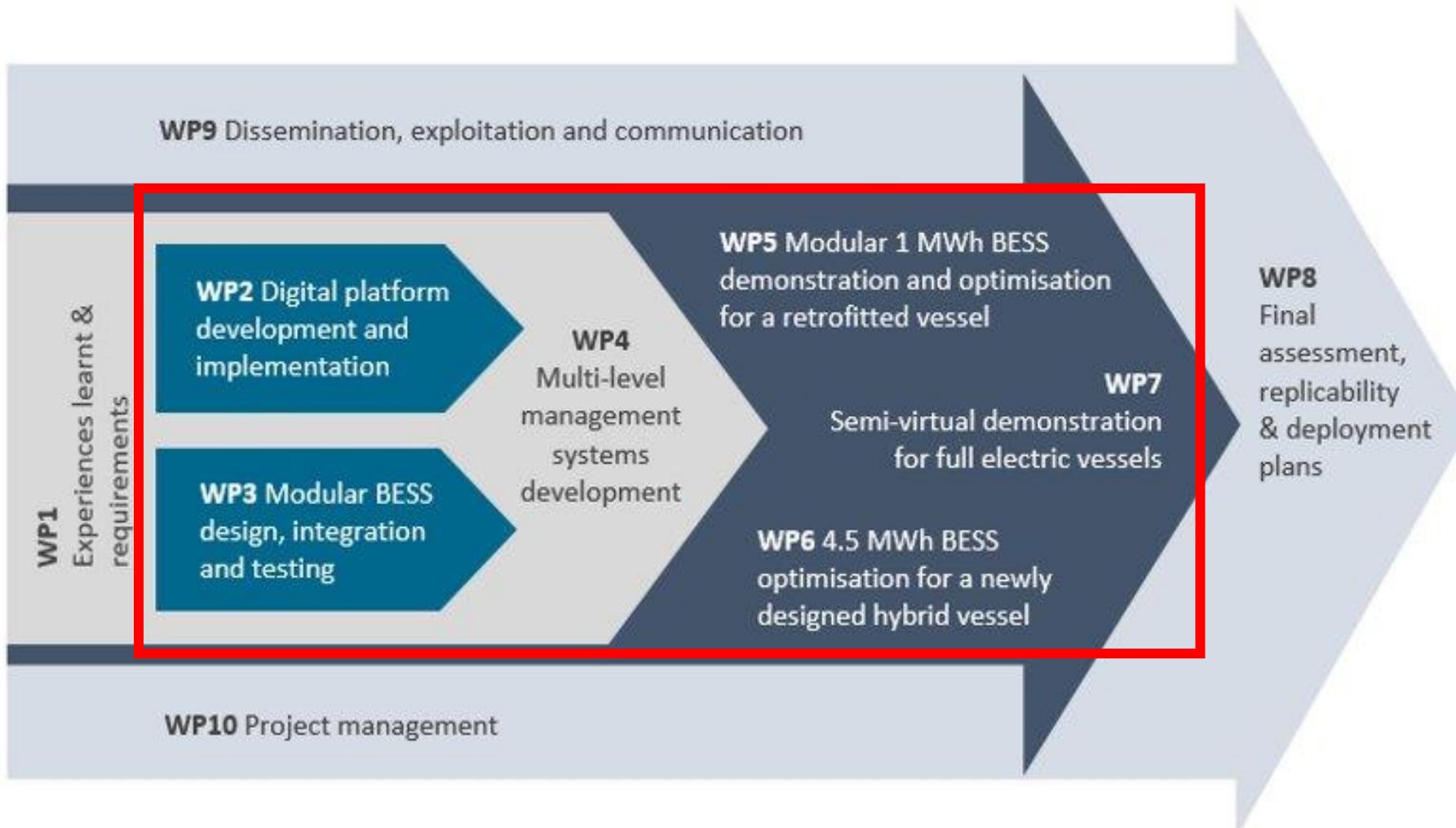
Consortium:

- 6 countries
- 11 complementary partners

Covering the entire value chain:

- 3 Research Technology Organization (CEA, VUB, Cidetec)
- 1 SME (SDI)
- 7 private large groups (Siemens, Corvus, Elkon, Solstad, Equinor, Ponant, In Extenso)





Today:

- WP2 Digital Platform development
- WP3 Modular and heterogeneous BESS
- WP4 Control algorithms
- WP5 and 6 Demonstration
- WP7 Full electric use cases



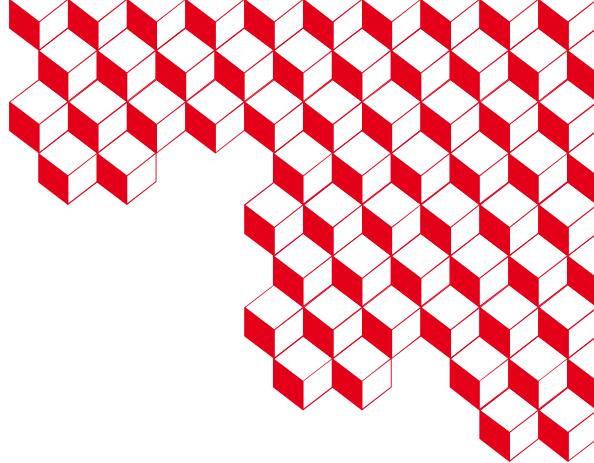
NEMOSHIP

KEYNOTE PRESENTATION ON SAFETY OF BATTERIES

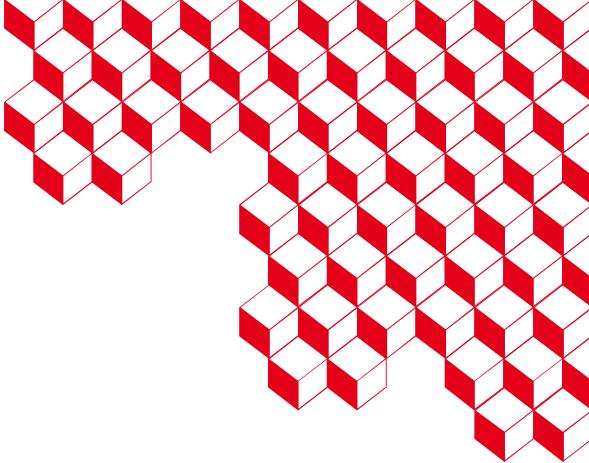
Magali Reytier, CEA



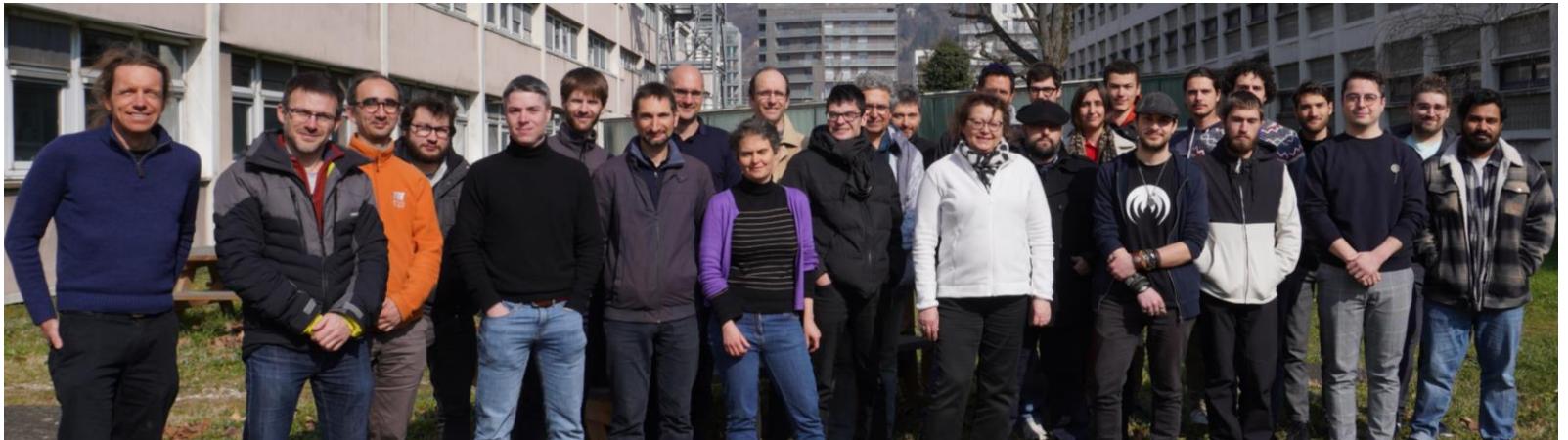
liten



Methodologies for Li-ion modules thermal runaway understanding and mitigation



Thank you



magali.reytier@cea.fr

Electricity and Hydrogen for Transportation Division
CEA Grenoble



Highlight on Li-ion batteries safety issues

Context of battery usage

- ▶ Rapidly increasing number of Li-ion batteries
- ▶ Higher volumic and gravimetric power & energy density
- ▶ Number of usages : consumer, transportation, energy storage from Wh to MWh

High level of safety expected

- ▶ Over the whole Value Chain and Life Cycle : manufacturer, stakeholders, users, recycle industry
- ▶ Li-ion battery fires that received large media coverage in the last two decades

*Review—Meta-Review of Fire Safety of Lithium-Ion Batteries: Industry Challenges and Research Contributions,
Laura Bravo Diaz et al 2020 J. Electrochem. Soc. 167 090559*



Car accidents



Underground parks



storages



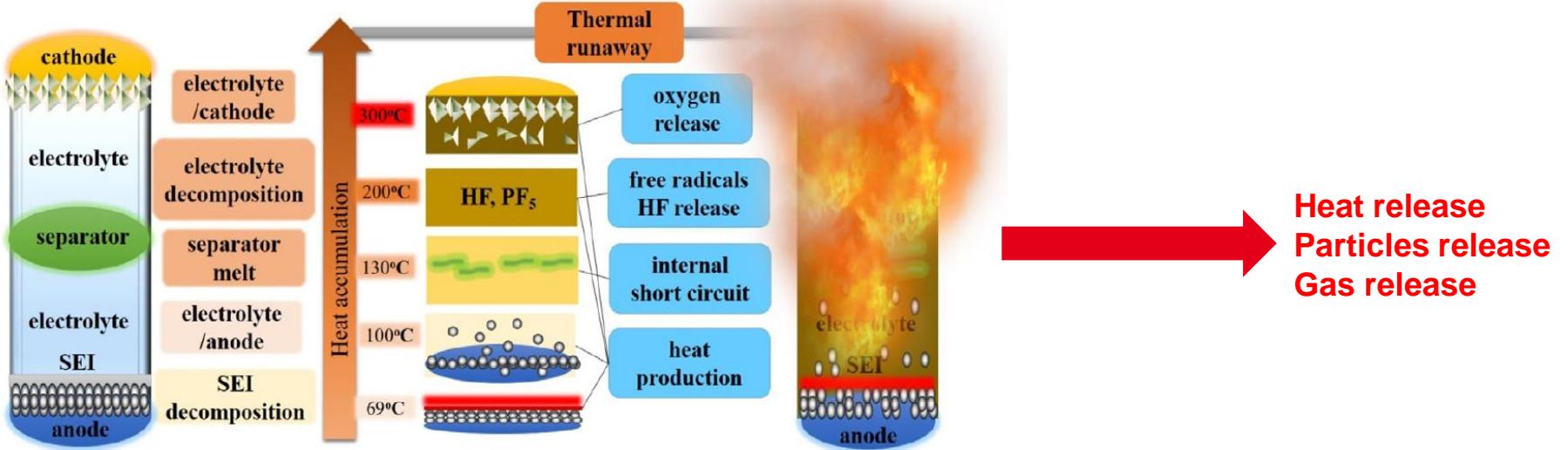
Highlight on Li-ion batteries safety issues



Thermal runaway (TR) evolution at cell level

External abuse
Mechanical
Electrical
Thermal

Internal defect



Wang et al, Progress in Energy and combustion science 73 (2019) 95-131

Factors of influence on TR and consequences

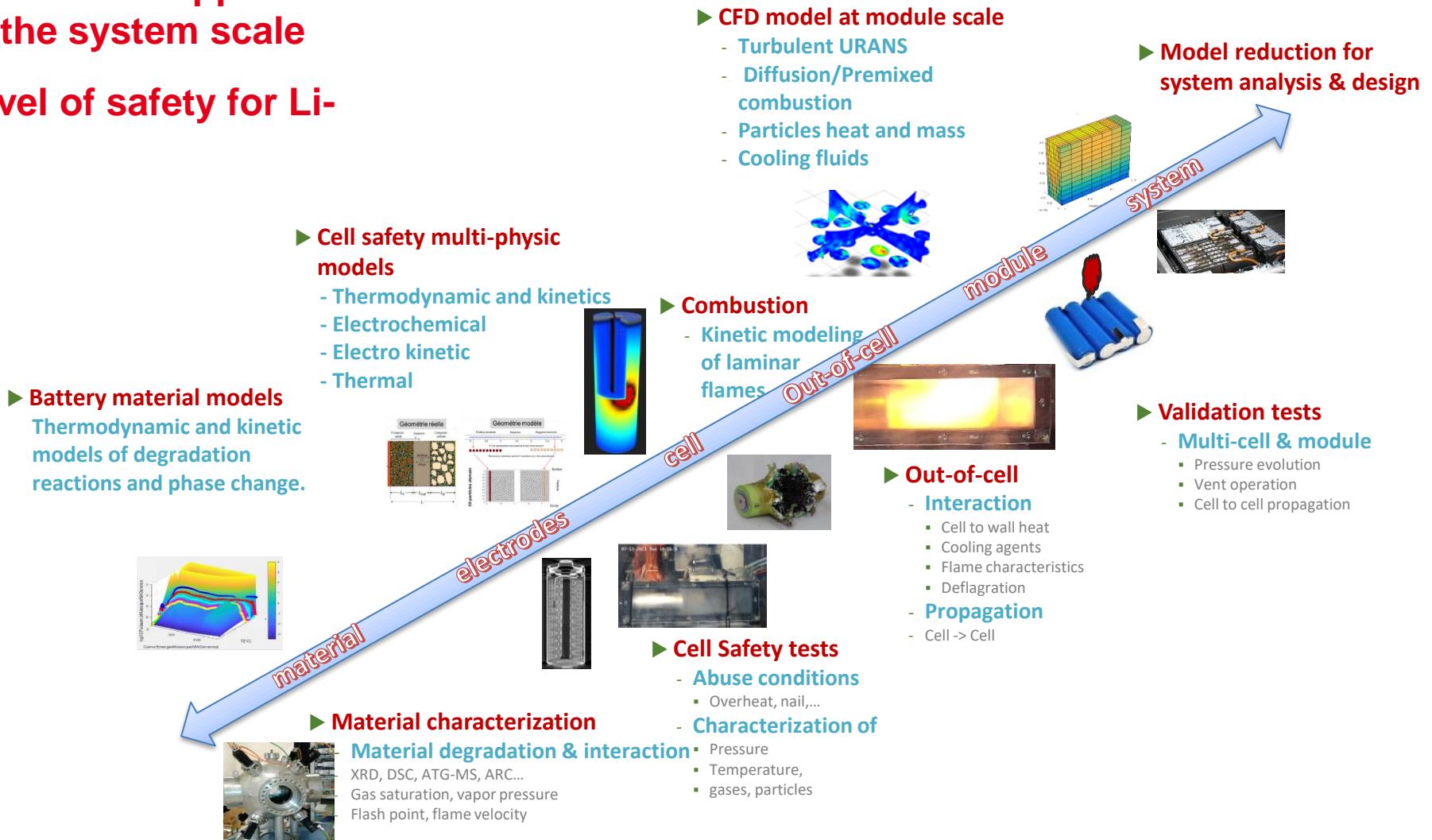
- ▶ Cell material reactivity, SoC and SoH
- ▶ Module and Pack design
- ▶ Venting, ignition, mitigation
- ▶ Environment

Highlight on Li-ion batteries safety issues



Toward a more predictive approach from material to the system scale

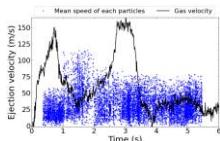
Ensure a high level of safety for Li-ion batteries



Highlight on Li-ion batteries safety issues

TR propagation at module or pack level : Can we assess and predict the different steps ?

1. TR of the first cell

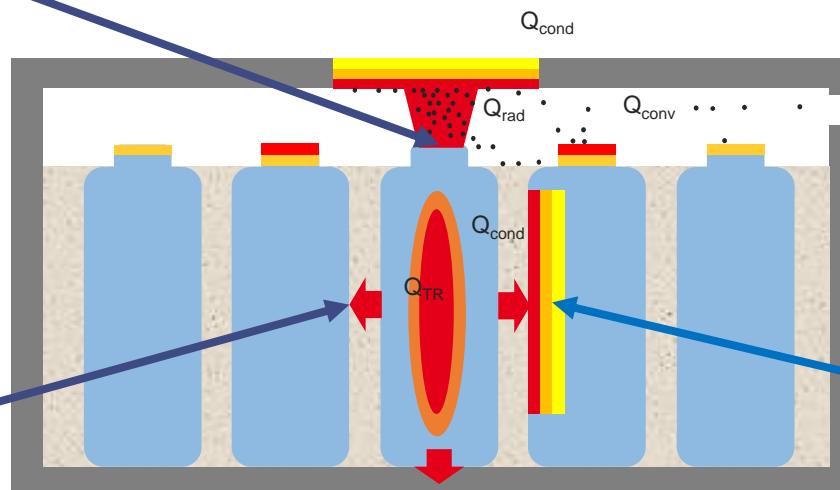


- Reaction kinetics & calorimetry
- Solid / gas evolution
- Mechanical behavior (vent, casing)



2. Heat and mass is transported

- Conduction (tabs, holder)
- Convection (hot gases; jet flame, particles)
- Radiation

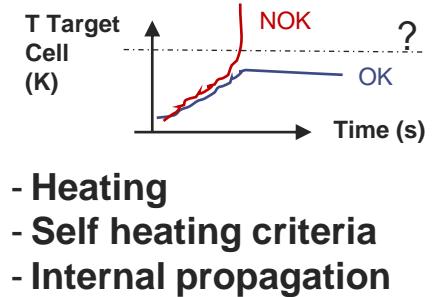


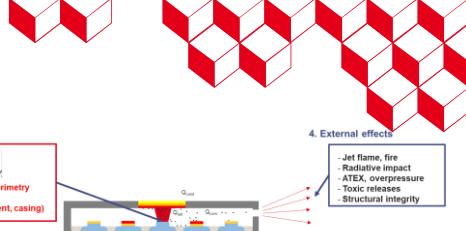
5. Detection and mitigation

4. External effects

- Jet flame, fire
- Radiative impact
- ATEX, overpressure
- Toxic releases
- Structural integrity

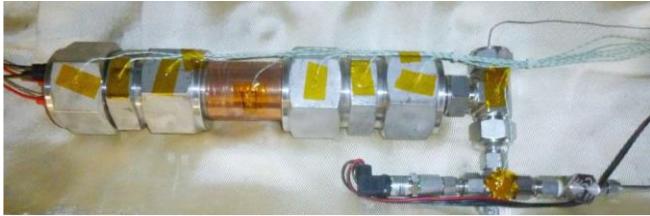
3. Impact (TR?) of other cells



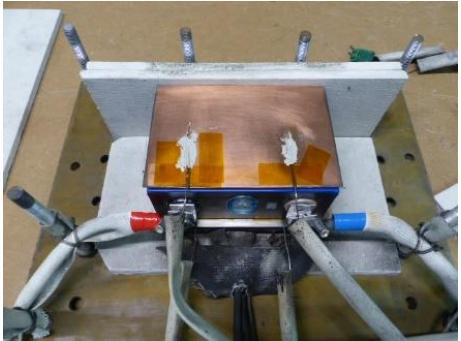


1. Advanced characterization of thermal runaway of a single cell

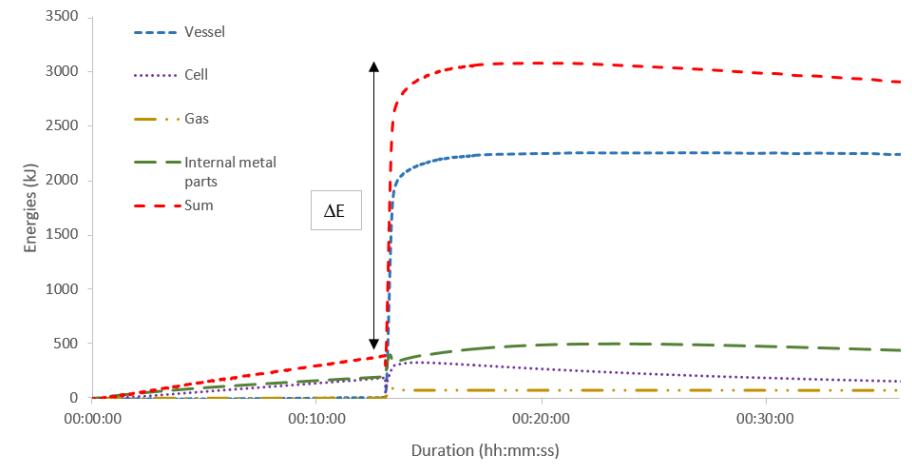
Energy and mass release during TR characterization in closed calorimeters



Closed vessel calorimeter form
0.5 L to 1400 L



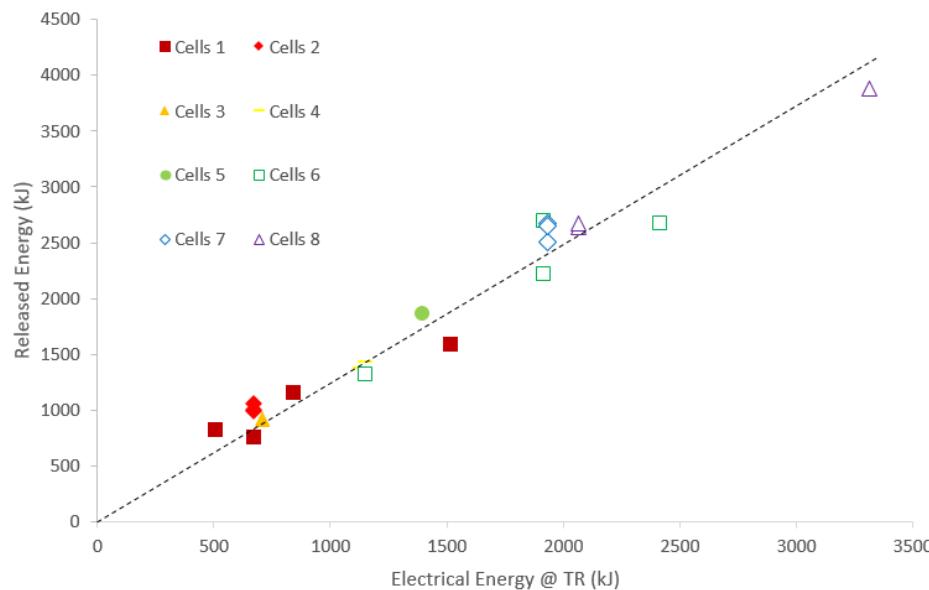
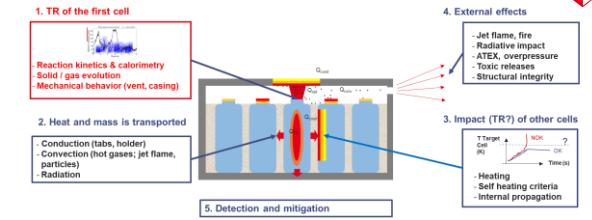
- Temperature & voltage evolution
- Heat balance : cell, ejectas
- Mass balance : gas, particles





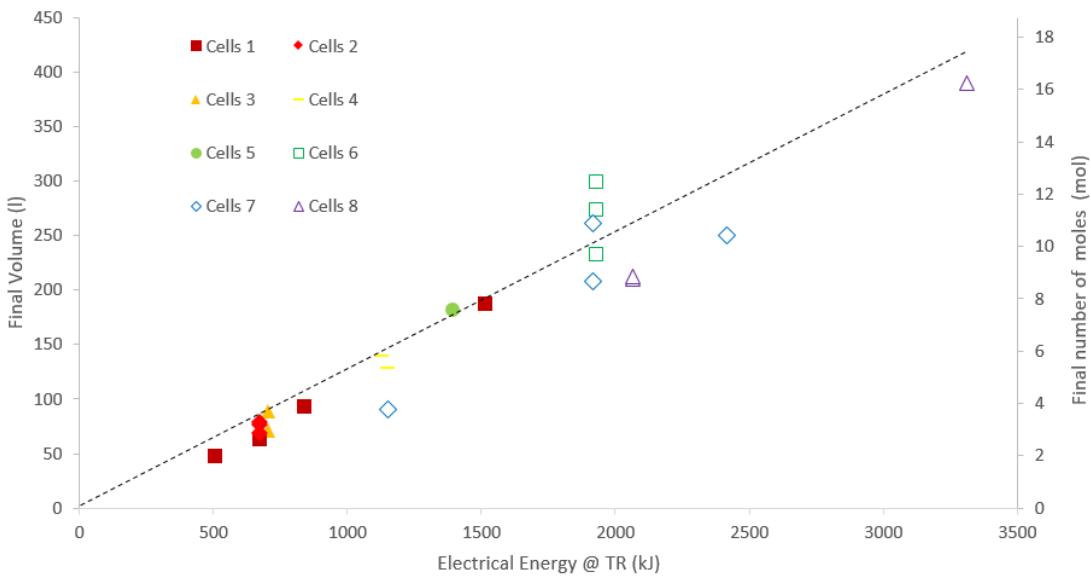
1. Advanced characterization of thermal runaway of a single cell

**Thermal runaway energy release for 22 tests
NMC prismatic & pouch from 53 Ah to 155 Ah,
overtemperature and overcharge, under vacuum**



TR energy versus stored electrical energy at TR :

$$\Delta E_{\text{TR}} / E_{\text{@TR}} = 1.25 \quad (R^2=0.95)$$



Gaz amount versus stored electrical energy at TR :

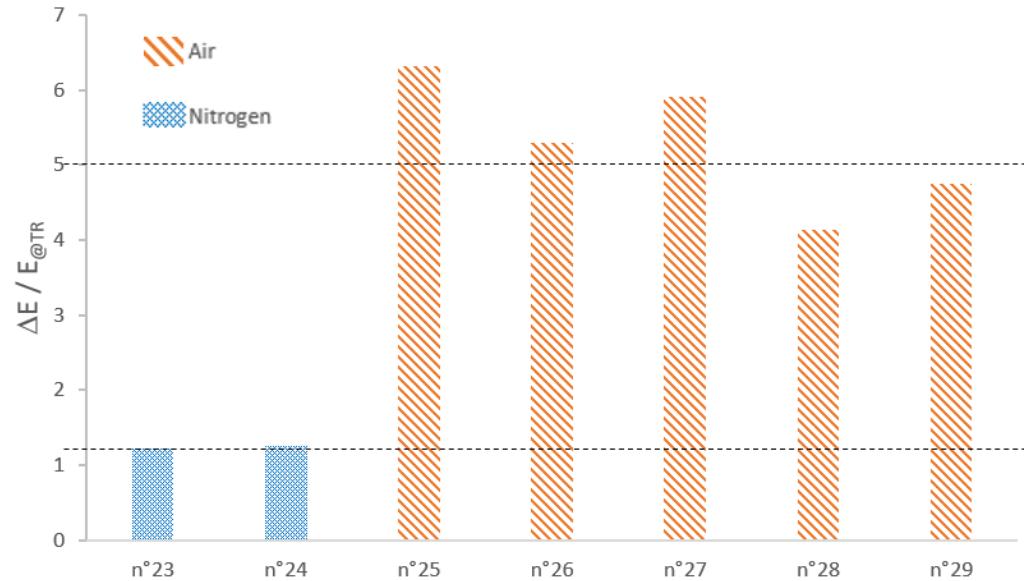
$$Q_g / E_{\text{@TR}} = 4.9 \times 10^{-3} \text{ mol} \cdot \text{kJ}^{-1} \quad (R^2=0.92)$$

Dubourg S. et al, Fire Safety Journal, 2025, special issue ISFEH11



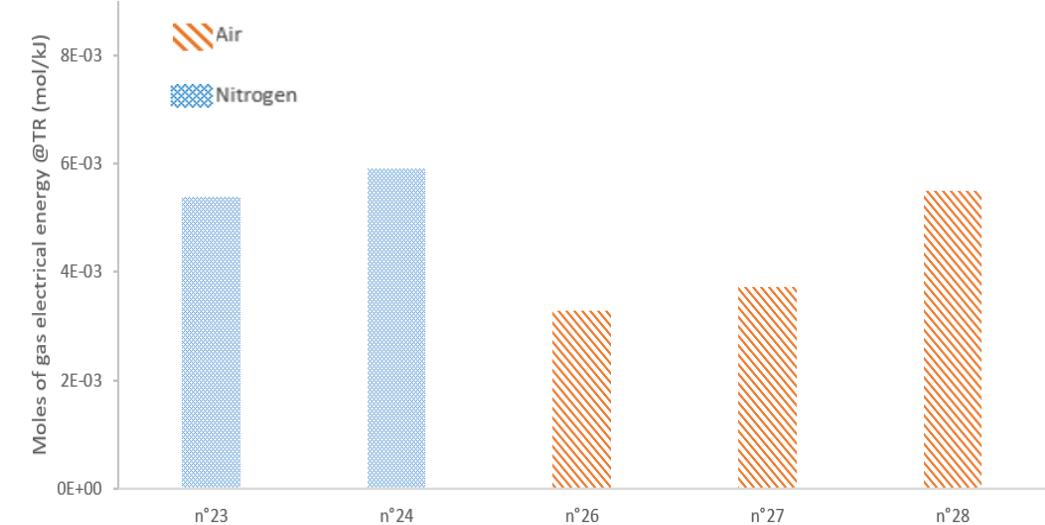
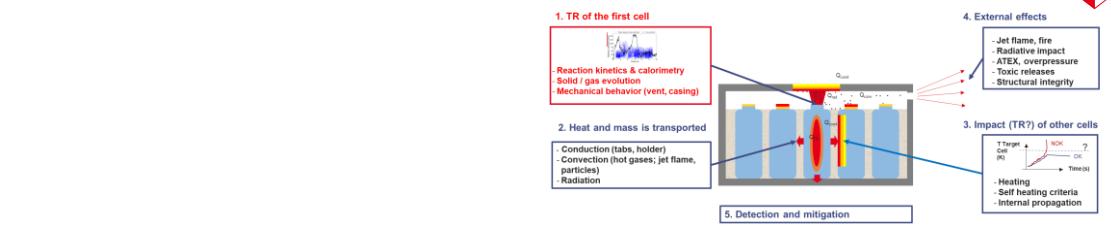
1. Advanced characterization of thermal runaway of a single cell

Impact of atmosphere (vacuum, nitrogen, air) on gas and energy releases



TR energy versus stored electrical energy at TR :

- In N₂ $\Delta E_{TR} / E_{@TR} = 1.25$ (as in vacuum)
- In air $\Delta E_{TR} / E_{@TR} = 5$ (more spread results)



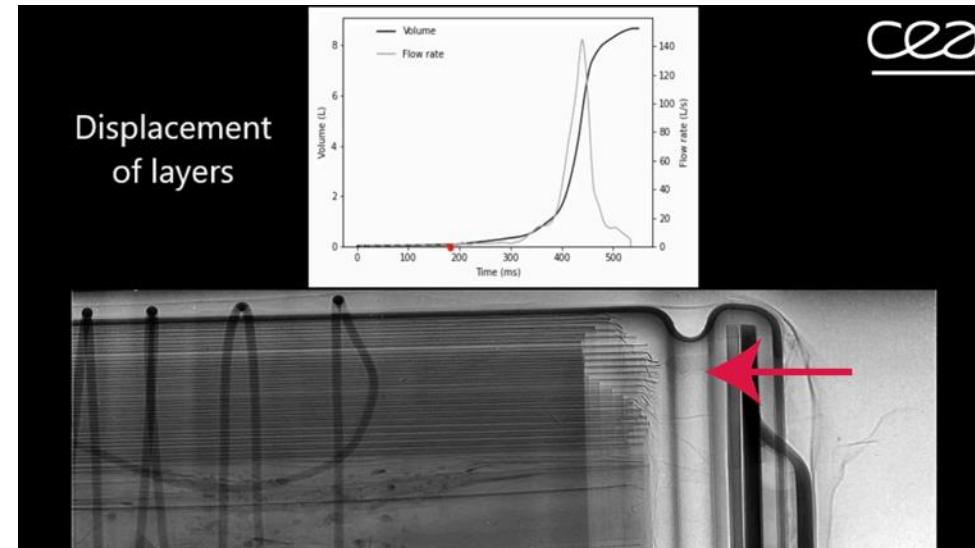
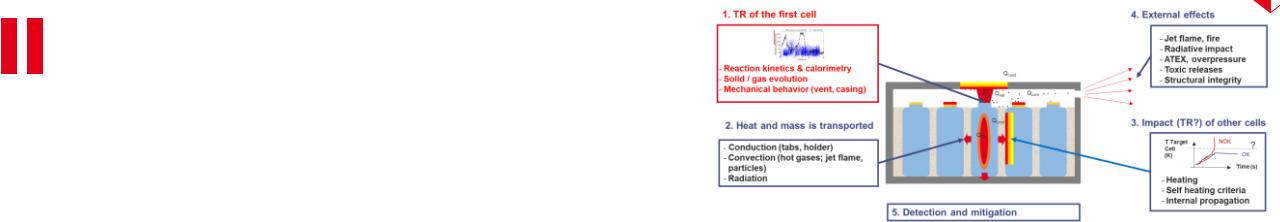
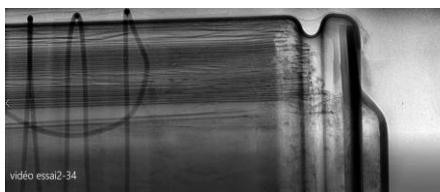
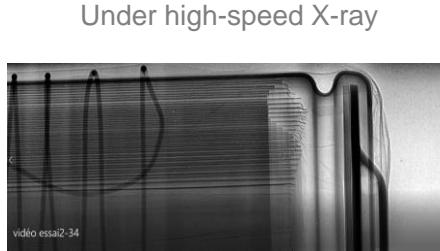
Gaz amount versus stored electrical energy at TR :

- In N₂ $Q_g / E_{@TR} = 5.7 \times 10^{-3} \text{ mol} \cdot \text{kJ}^{-1}$ ($R^2=0.92$)
- In air $Q_g / E_{@TR} = 4.2 \times 10^{-3} \text{ mol} \cdot \text{kJ}^{-1}$
- In vacuum $Q_g / E_{@TR} = 4.9 \times 10^{-3} \text{ mol} \cdot \text{kJ}^{-1}$



1. Advanced characterization of thermal runaway of a single cell

Operando high speed X-Ray (ESRF)



Improve the understanding the internal space-time evolution of TR

Charbonnel J. et al., ACS Applied Energy Materials 5, n° 9, 10862-71 (2022).

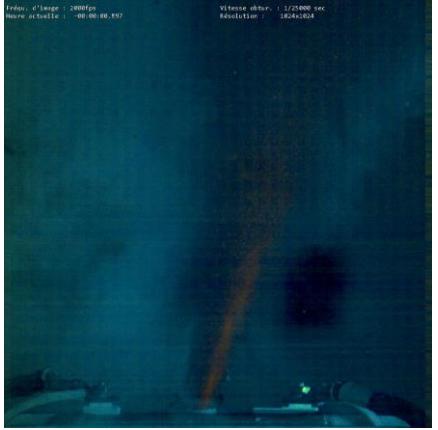
Darmet N. et al., ACS Applied Energy Materials 7, n° 10, 4365-75 (2024)

1. Advanced characterization of thermal runaway of a single cell

Fast camera imaging (Visible and Infra-red)



Electrolyte ejection



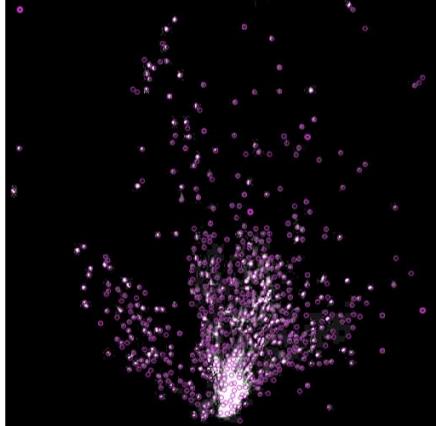
Gas and particules ejection



Ignition



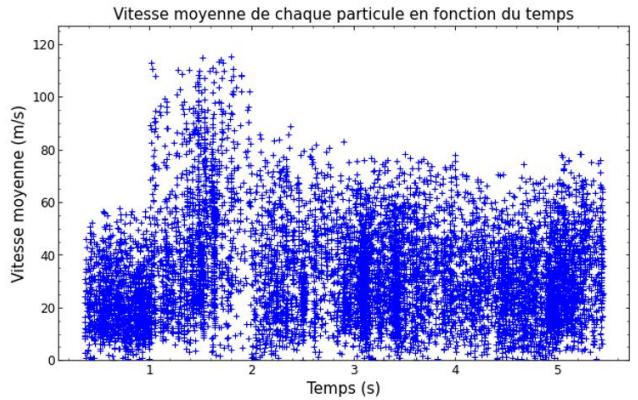
Flame extension



Particles tracking



Trajectoires restantes



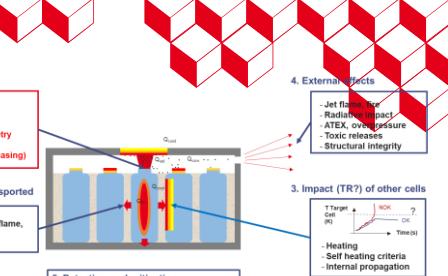
Average particles velocity

→ Venting and jet flame space-time evolution of TR

→ Automatic particles tracking and average velocity determination

L.Sponem PhD Thesis

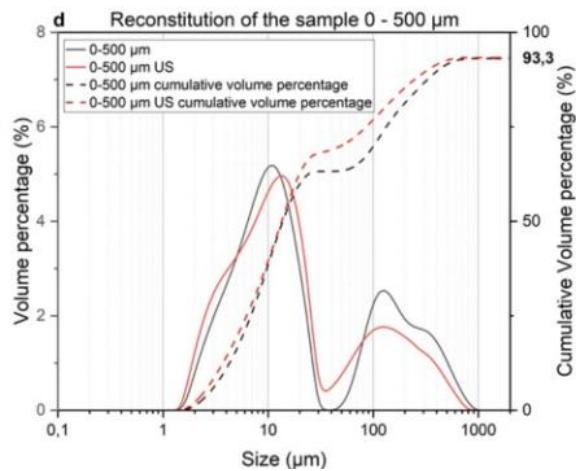
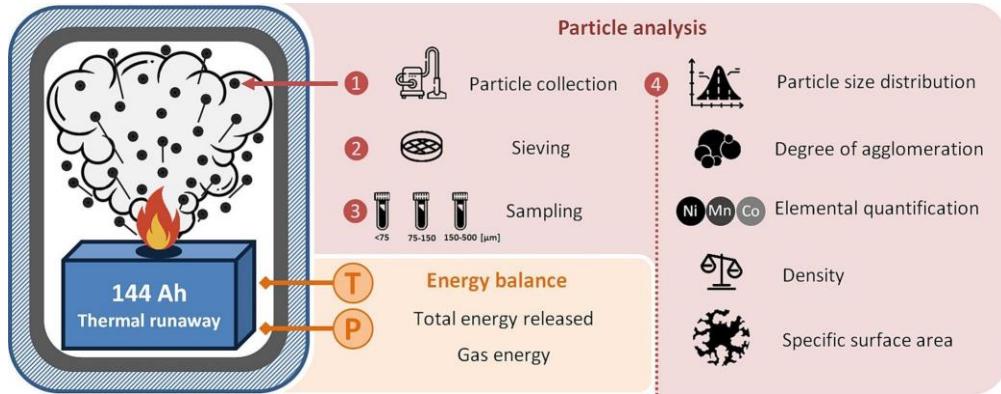
L.Sponem et al, Proceedings ISFEH11, june 2025





1. Advanced characterization of thermal runaway of a single cell

Particles emissions characterization



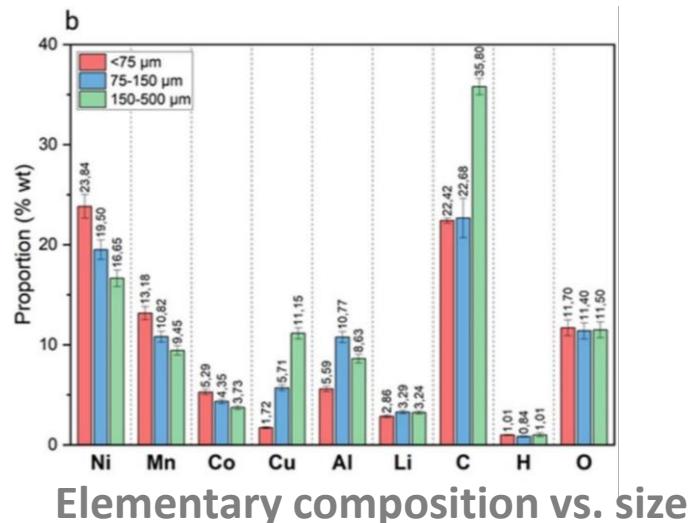
Size distribution

Density and specific surface area evolution with particle size.

| Sample | ρ ($\text{kg} \cdot \text{m}^{-3}$) | SSA ($\text{m}^2 \cdot \text{g}^{-1}$) | $\text{SSA}_{\text{Sphere fcc}}$ ($\text{m}^2 \cdot \text{g}^{-1}$) |
|------------|--|--|---|
| < 75 μm | 2958 | 6.621 | $4.88 \cdot 10^{-2}$ |
| 75-150 μm | 2845 | 3.690 | $4.12 \cdot 10^{-3}$ |
| 150-500 μm | 2689 | 2.131 | $1.68 \cdot 10^{-3}$ |

Density and specific surface area

T. Grosssetete *et al*, J. of energy storage, vol 124, 2025, 116666

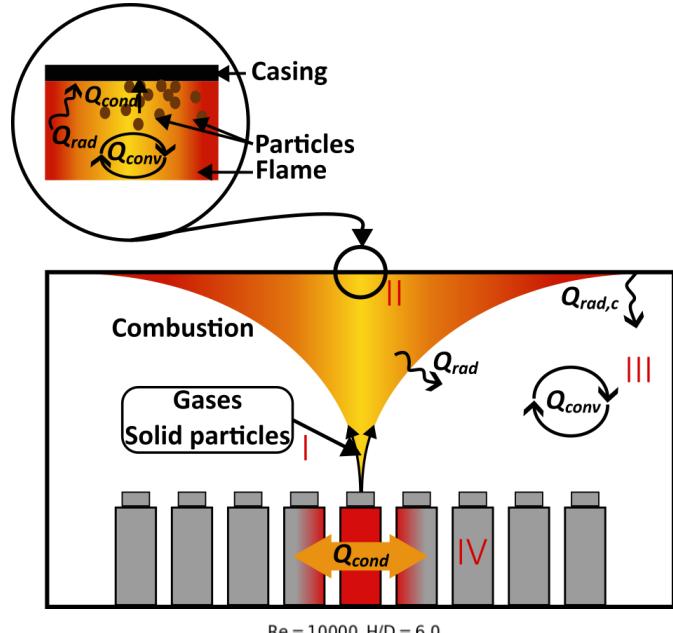


Elementary composition vs. size

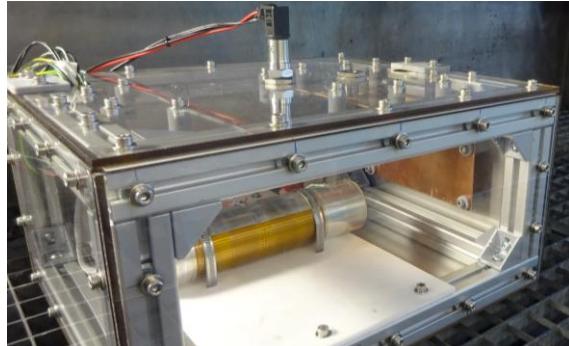


2. Heat and mass transfer from TR cell to surroundings

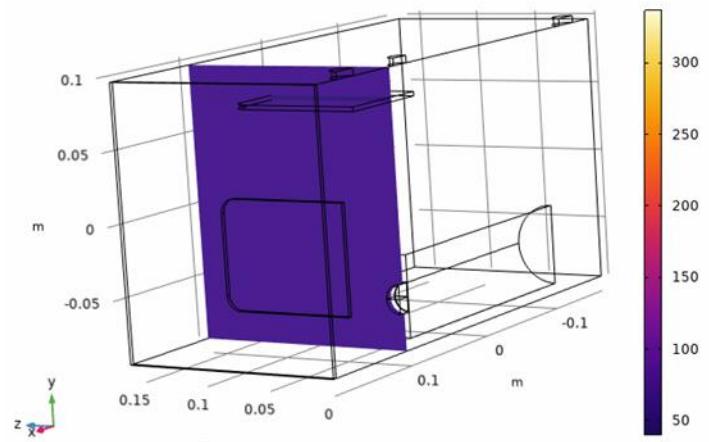
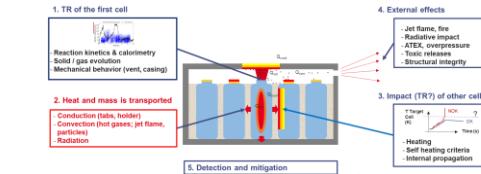
Heat transfer characterization and modeling



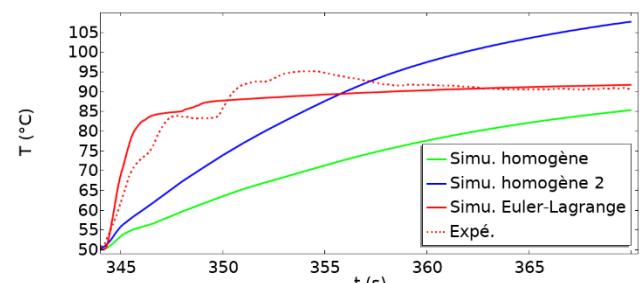
Literature data spread (w/o particles)



Ejecta impact on instrumented plate



Ejecta impact on the front plate



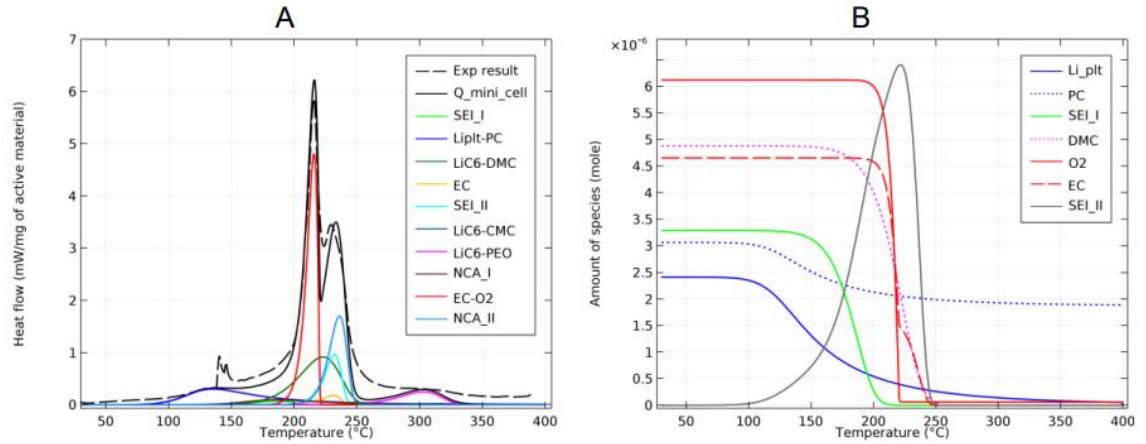
Model sensitivity (Eulerian vs. Lagrangian)



3. Onset and internal TR in target cells

Heat transfer from surroundings

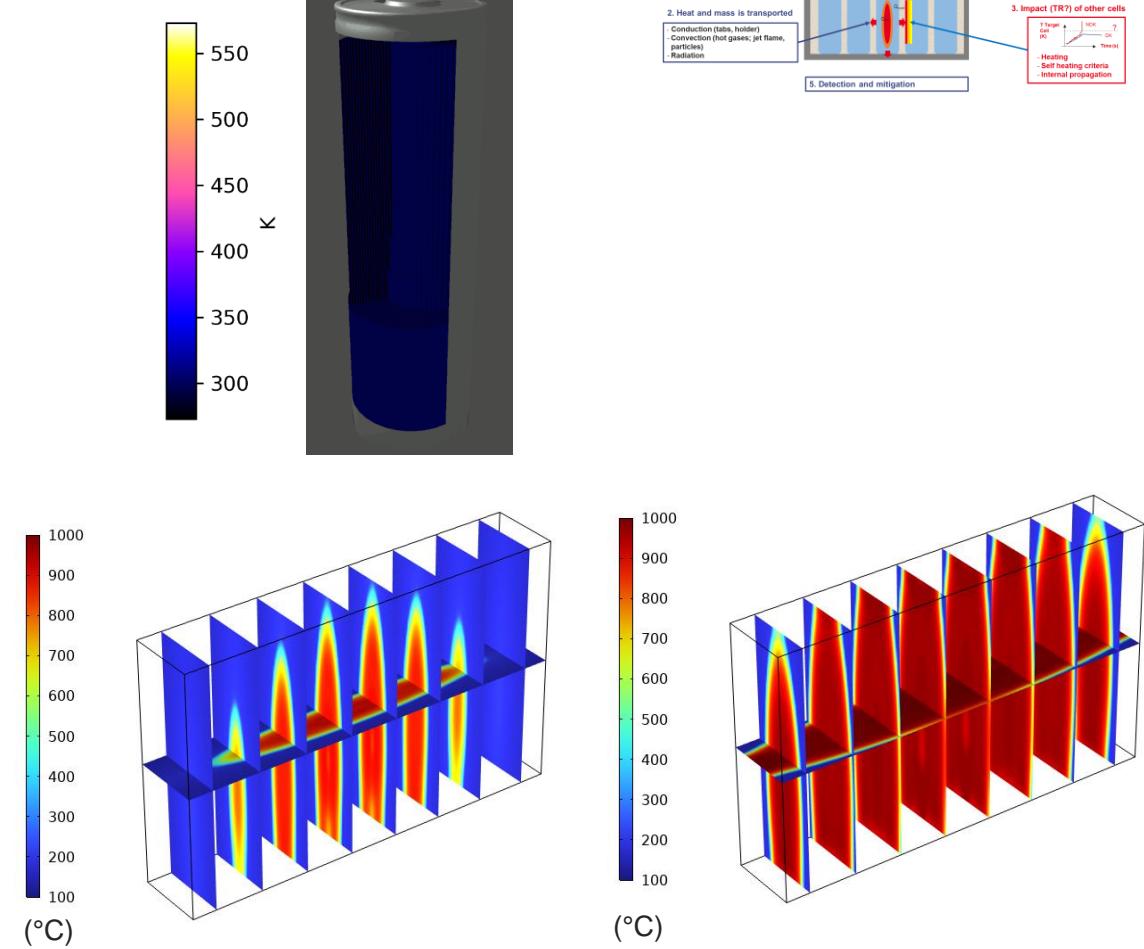
Internal self heating model (DSC/ATG based)



Cell and stack thermal properties

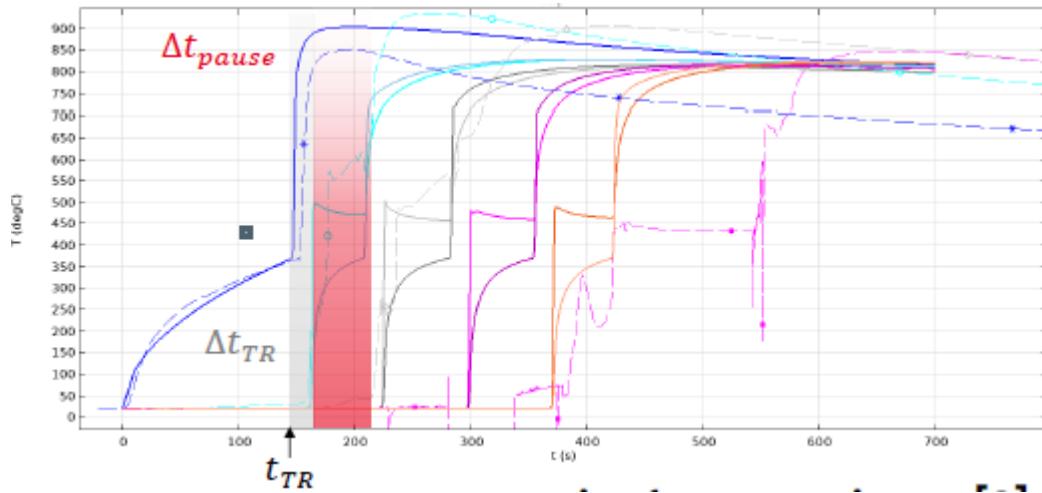
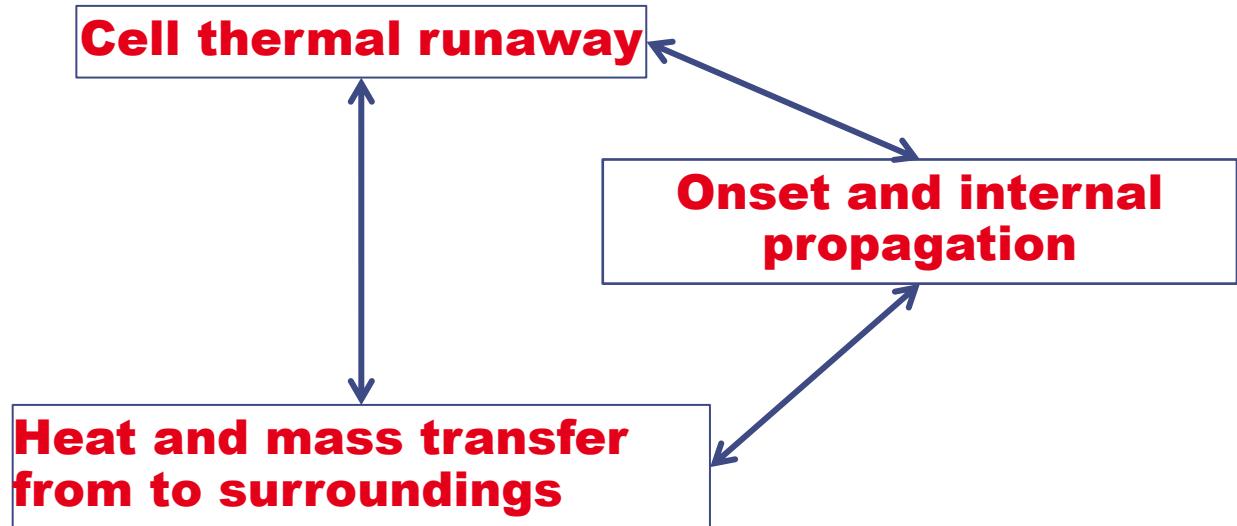
Ridha Omrani. Experimental study and modeling for the safety of Li-ion batteries. Material chemistry. Université Grenoble Alpes, PhD Thesis, 2022

Juliette Charbonnel *et al.* Chemical Engineering Journal 494 (2024) 153234



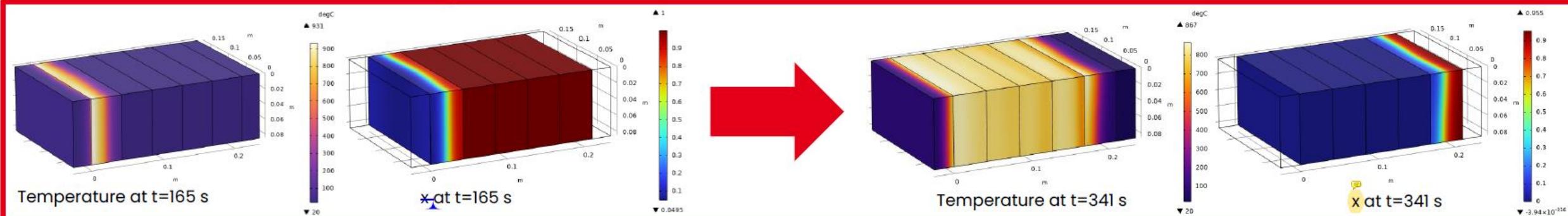
Temperature evolution during TR in cylindrical, and a prismatic cell

1+2+3 : Methodology for module propagation simulation



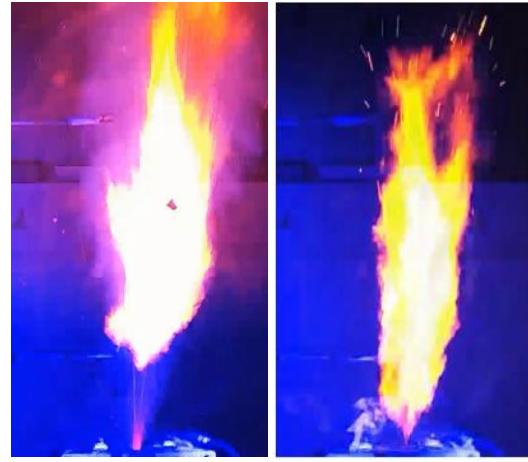
Model comparison to experiments from Schöberl et al., 2024,
eTransportation19: 100305

TR propagation

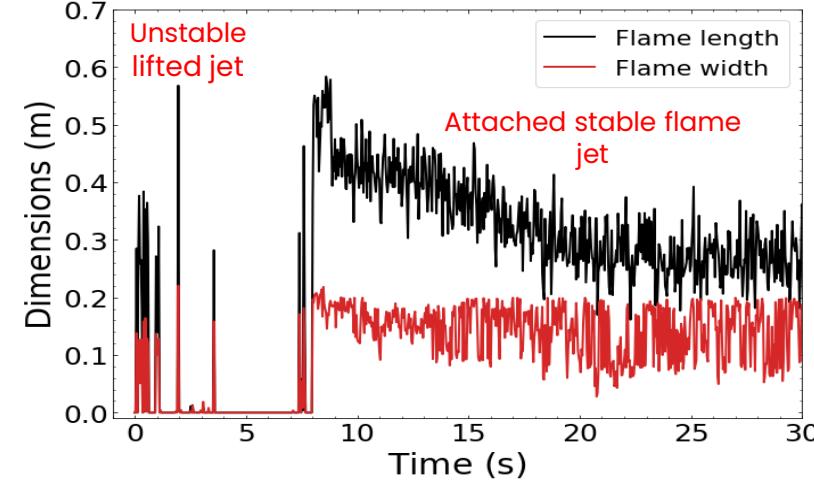


4. External effects

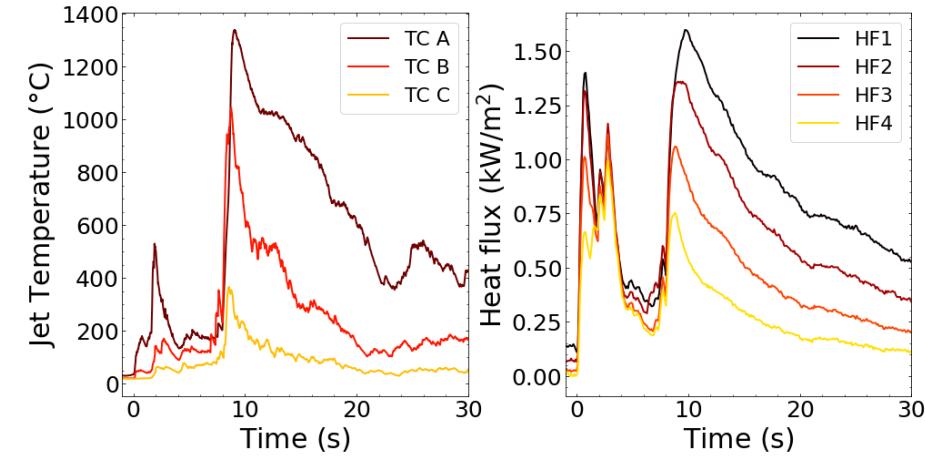
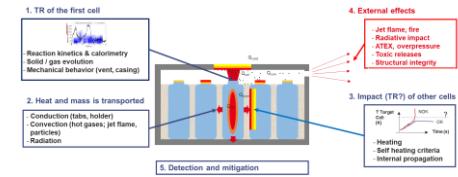
Jet flame characterization



2 flame regimes (HD camera)



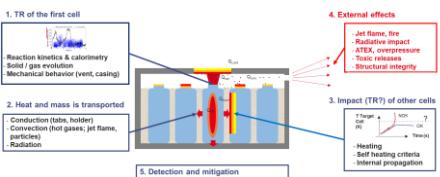
Unstable lifted jet then attached stable flame jet



Measured temperatures and heat flux

4. External effects

Shock wave in open field



Cylindrical 18650 GEN3

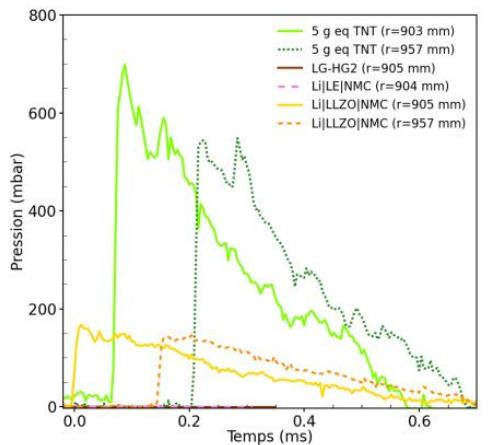
Gr|NMC

$\tau_{\text{TR}} \sim 500 \text{ ms}$

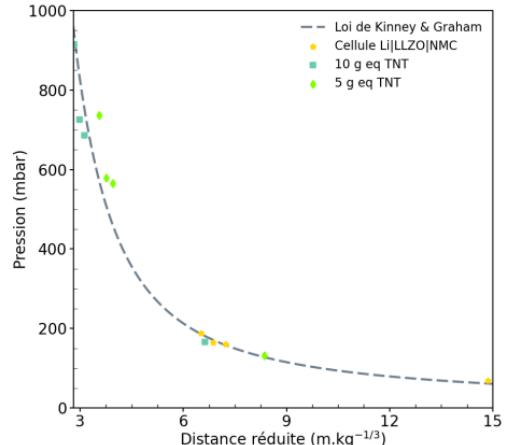
Cylindrical 18650 ASSB

Li|NMC

$$\tau_{\text{TR}} \sim 10 \text{ ms}$$



Measured aerial overpressure



Kinney & Graham scaling law

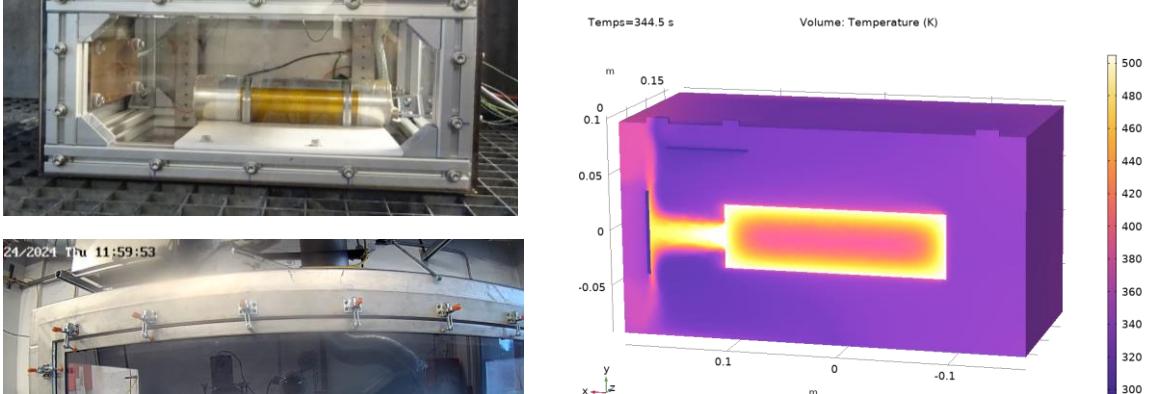
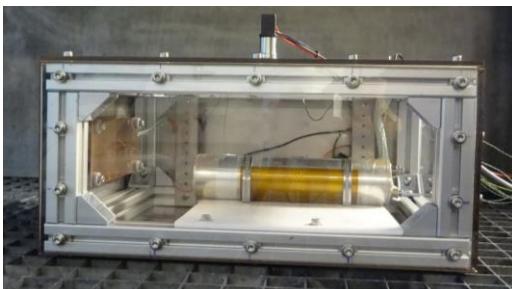
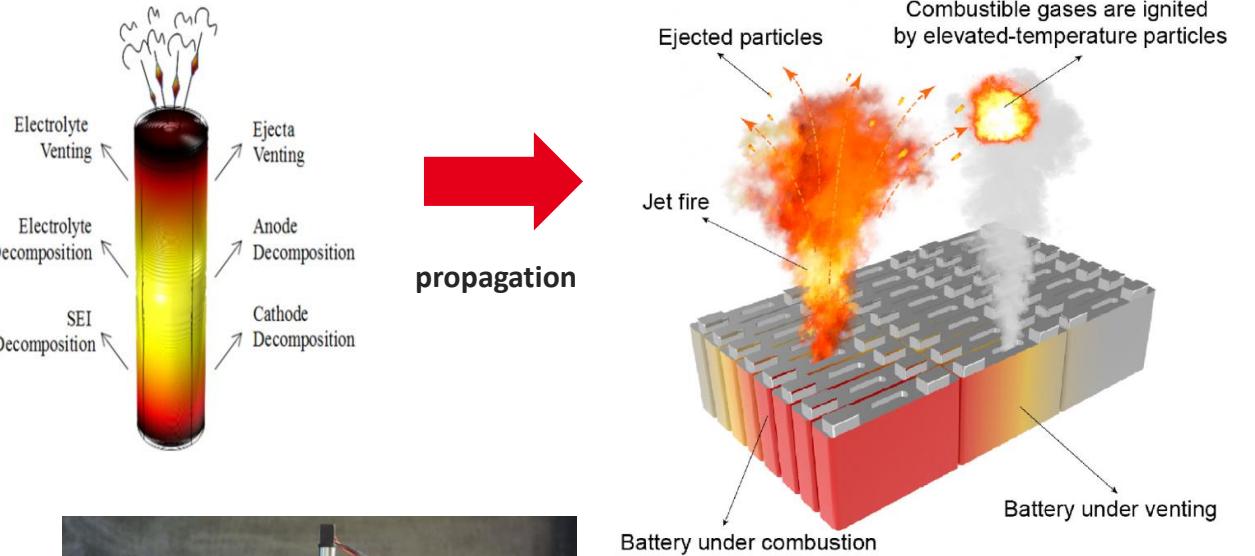
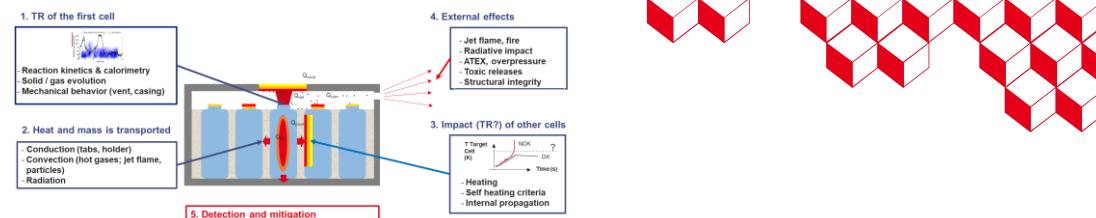
5. Detection and mitigation

- Ongoing Multiphysic approach
- From cell alone to cell in a module or pack
- Try to detect as soon as possible (R100.3)
- Different signals and thresholds
- **Detection to be optimized with cell capacity, pack design**

Table 3. Evaluation of the different sensors on three categories. Signal clarity describes how close the detection signal comes to a step function and how easy it is to evaluate it, whereas sensor feasibility evaluates how easy the sensor can be deployed. Grading goes from (+) good, to (0) neutral to (-) bad.

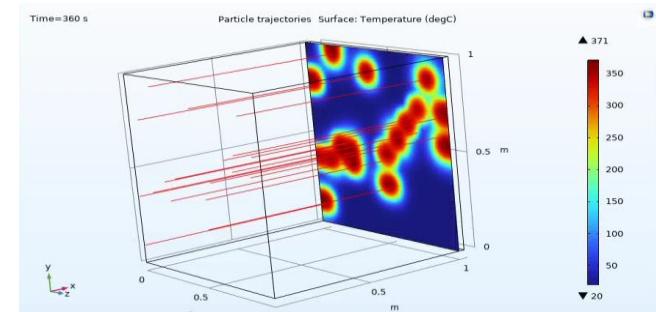
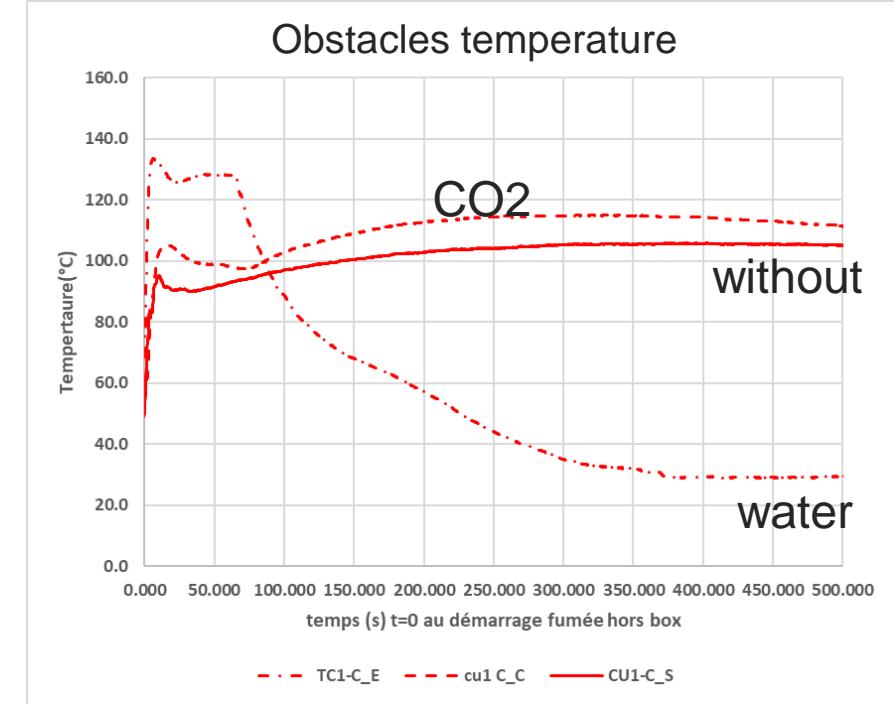
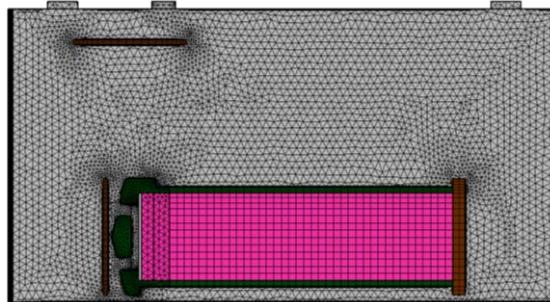
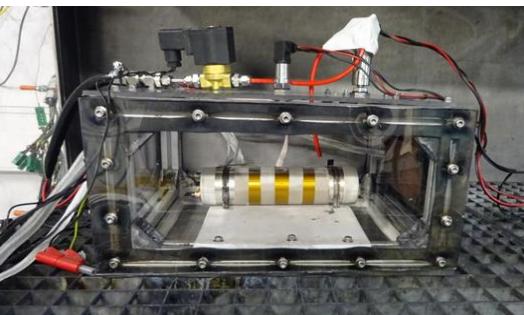
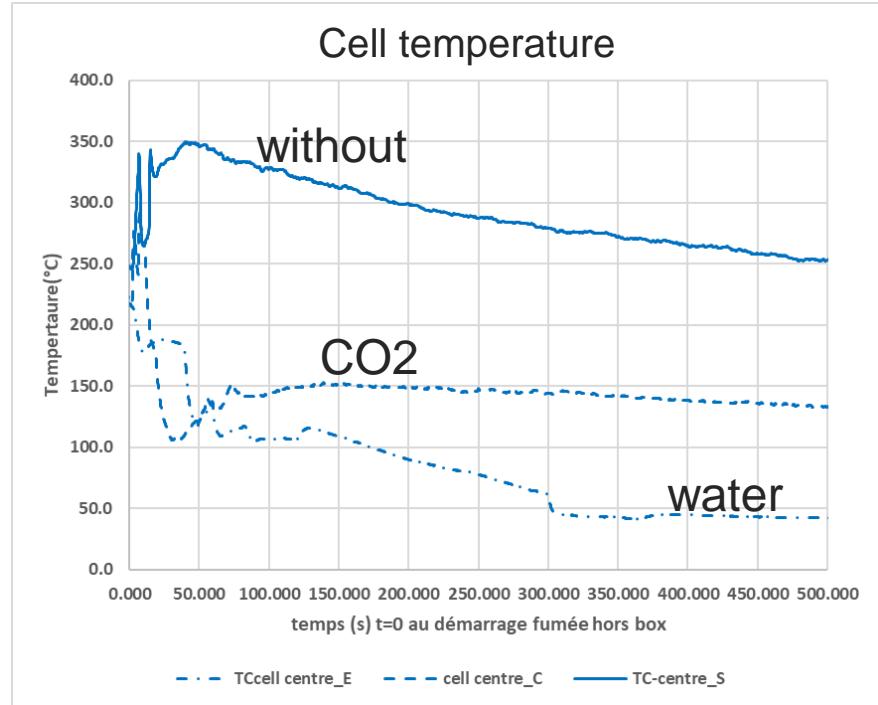
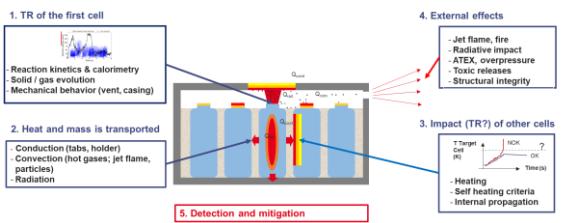
| Sensor | Detection Speed | Signal Clarity | Sensor Feasibility |
|-------------------|-----------------|----------------|--------------------|
| S1 voltage | - | + | + |
| S2 gas | + | + | - |
| S3 smoke | - | 0 | 0 |
| S4 creep distance | - | - | + |
| S5 temperature | 0 | 0 | 0 |
| S6 pressure | + | - | + |
| S7 force | + | - | 0 |

Koch *et al*, Batteries 2018, 4, 16





5. Detection and mitigation

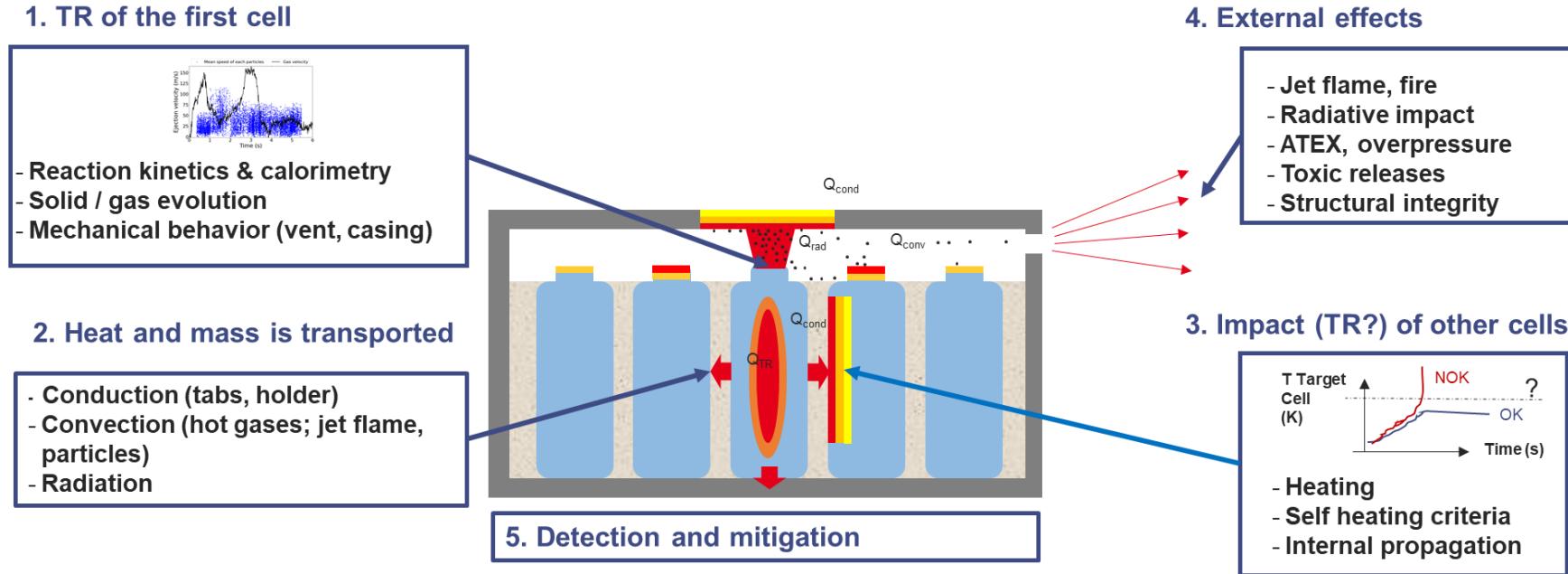


- Water cooling >> CO2
- Gas and particules to be taken into account
- Other extinguishing and cooling media under study

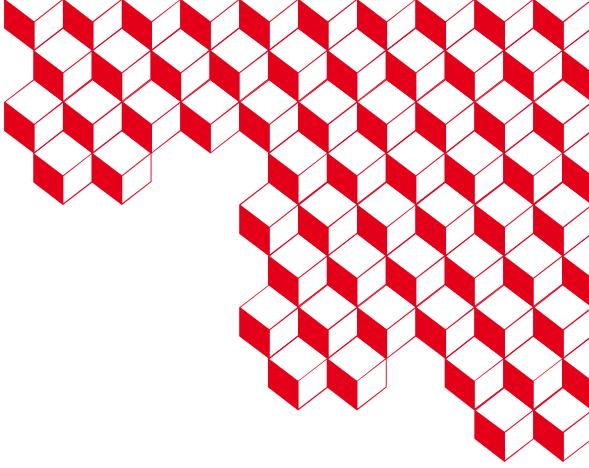
CONCLUSION



TR propagation at module or pack level : Can we assess and predict the different steps ?



→ **Necessity to get quantitative and reliable experimental characterizations on these 5 steps and to consolidate through predictive modeling**



Thank you



magali.reytier@cea.fr

Electricity and Hydrogen for Transportation Division
CEA Grenoble



NEMOSHIP

Q&A FOR
Keynote presentation on safety of batteries / Magali Reytier,
CEA



NEMOSHIP

MARINE BATTERIES SAFETY

Lars Petter Larsen, Corvus

NEMOSHIP 2026

Transforming battery safety
and design with **advanced
analytics and digital twins**

Presented by

Lars Petter Larsen

Global Service Program Manager

Corvus  Energy





Safety & Design

Driving safety further

Continuous Improvement

Learning from 800+ projects
Sustainable Engineering

Emergency Management

24/7 support
Emergency response team
Specialists teams

Continuous Monitoring

ESS performance analysis via
Vessel Information Portal data

In-house Competence

R&D
Maritime DNA
Risk analysis
FMEA

Quality Control

ISO Qualified
Multi stage development
Testing

Information Sharing

Classification Societies
Shipowners
System Integrators
Authorities

**ESS
Safety**

Driving safety on all levels

Examples

Design Phase

- Close cooperation
- Sizing according to the operational profile
- Application engineering
- HAZID
- Pre-installation check

System

- Cell chemistry
- Single cell TR insulation
- BMS (Battery Management System)
- Continuous Monitoring

Battery Room

- Class requirements
- Cooling
- Gas detection
- Fire extinguishing system
- Monitoring

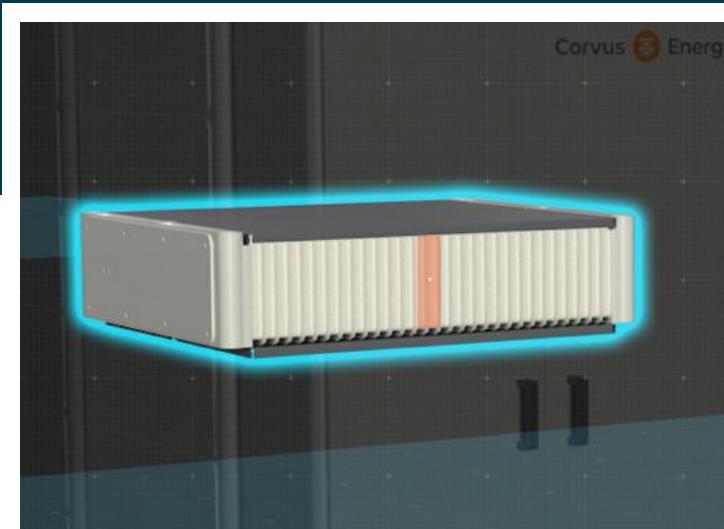
Operations

- Online monitoring
- Safety training of crew and operators
- Emergency response team

System Safety

Passive Single-Cell Thermal Runaway Insulation

Integrated thermal runaway (TR) gas exhaust system



Cell-level Insulation

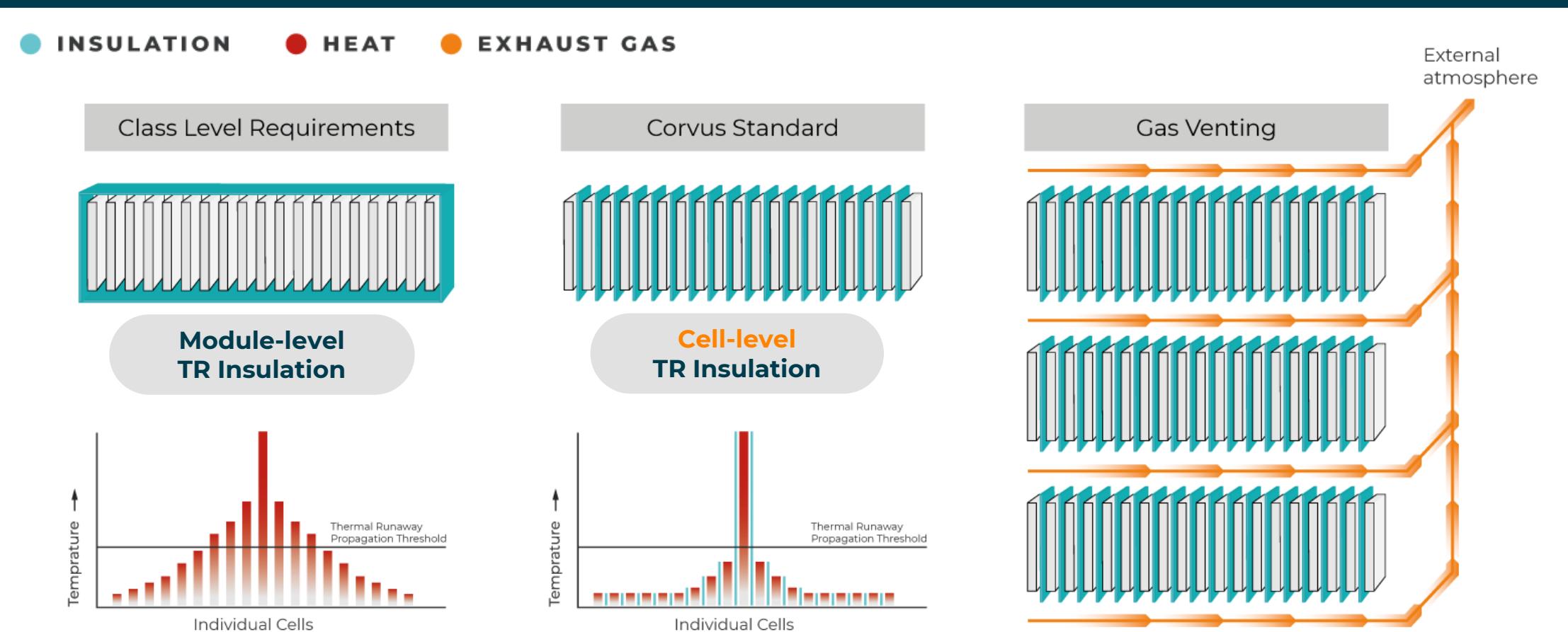


TR gas is easily vented to external atmosphere

System Safety

Passive Single-Cell Thermal Runaway Insulation

Corvus design exceeds class level requirements



System Safety

Passive Single-Cell Thermal Runaway Insulation

Corvus design exceeds class level requirements

How Corvus Passive-Single Cell Propagation protection works

- Each cell is thermally isolated from neighboring cells
- Debris ejected from a cell in TR will not create cascading events
- Hot gasses emitted from the TR cell are channeled to the module's exhaust port
- Cell fuses on both positive and negative terminals of the cell

Exceeding class requirements



Class requirement:
module-level TR Protection

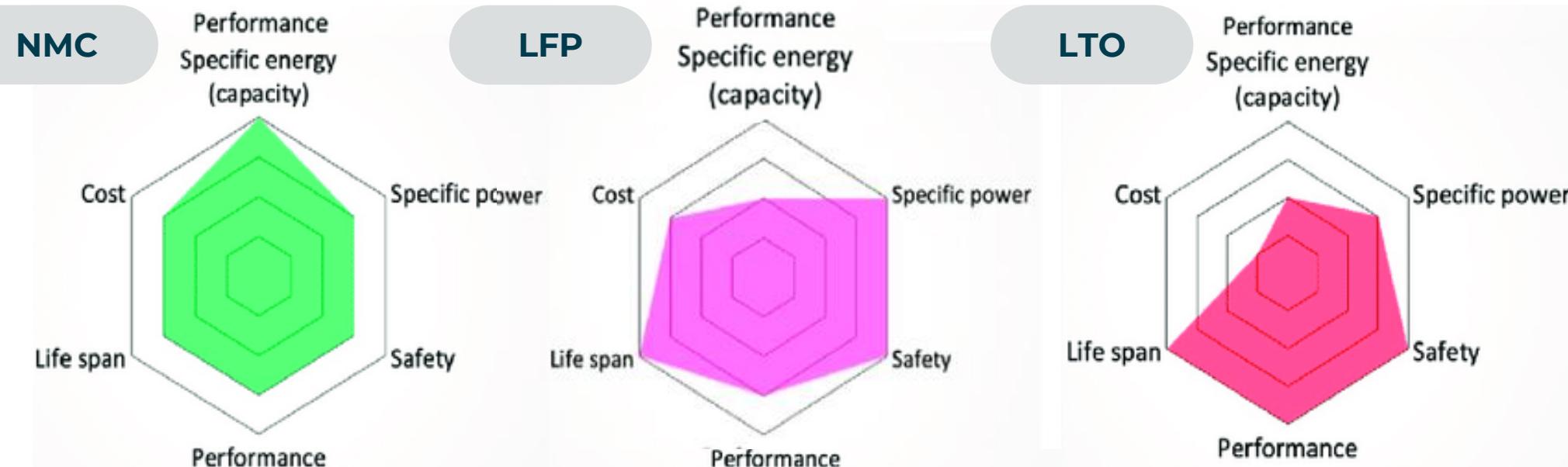


Corvus standard:
cell-level TR Protection

Design Feature

Battery Cell Chemistry

Comparison charts: NCM, LFP and LTO

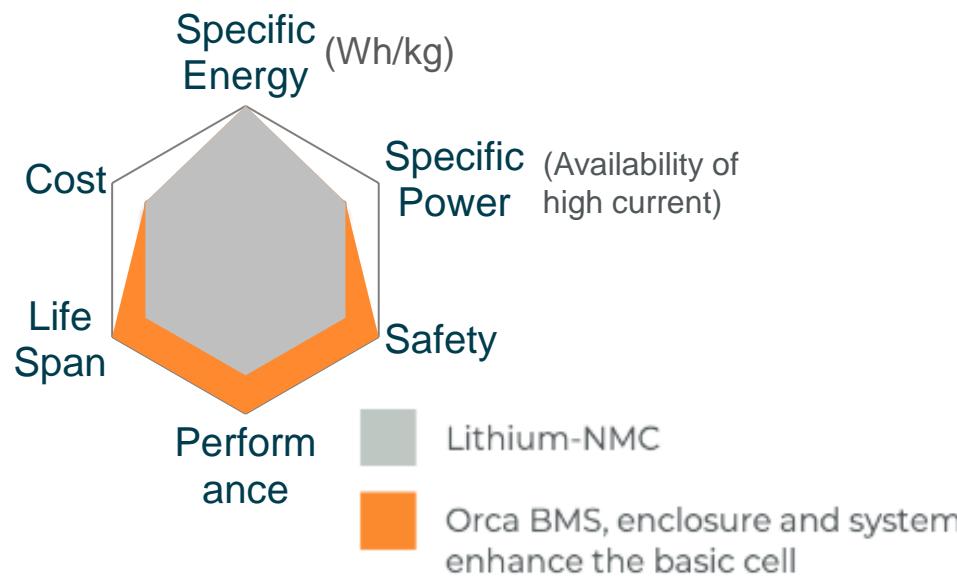


System Safety

Corvus Battery Management System

BMS enhances the basic cell chemistry

Example



Cell Balancing

BMS cell balancing enhances performance, life span and safety

Monitoring and equalizing the voltages and state of charge among the cells helps to prevent damage and optimizes function

System Safety

Corvus Battery Management System

Industry-proven, state-of-the-art BMS

Key Benefits

Supports system safety, lifetime and operational predictability



Safety
Disconnect

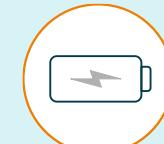


Supports
Lifetime

Monitors



Cell
Temperature



Charge /
Discharge Limits



Voltage



Current

New Design

Modular Design Approach

Supports quality and cost efficiency

Modularized design, where cell-agnostic components can be applied across product lines offers many benefits.

Modular design supports improved:

- Product quality
- Performance reliability
- Cost efficiency
- Production timelines



Blue Whale
ESS

Dolphin Energy
NxtGen ESS

Scope

Battery safety and design

- **Optimal size with digital twin**
 - Load profiles: Simple and complex
 - Tuning parameters
- **Optimal operation with advanced analytics and digital twin**
 - Operational profile can be different
 - How to optimize performance and lifetime
- **Diagnostics and prognostics**

Digital Twin

A digital model of a physical battery system

Given the operational profile, the digital twin model can:

- Simulate the electrical and thermal performances
- Simulate the degradation over time
- Takes BMS (Battery Management System) limits into account

Configuration

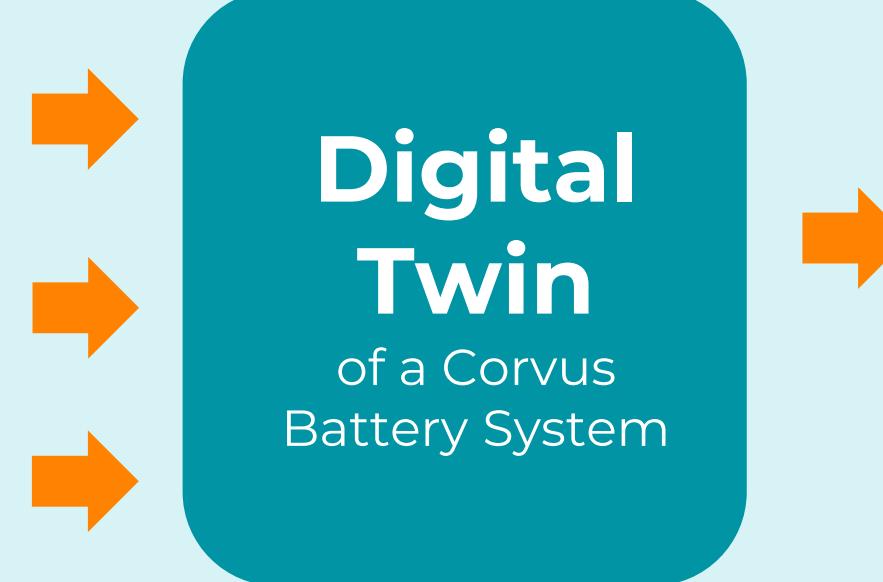
Product type, No. of modules and packs, SOC and SOH limits

Operational Profile

Time vs. Power/Current

Initialization

SOH, SOC, Temperature



Performance

Electrical & Thermal Degradation

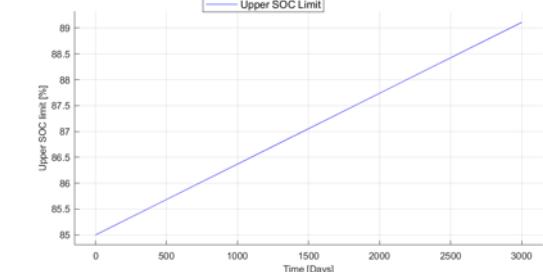
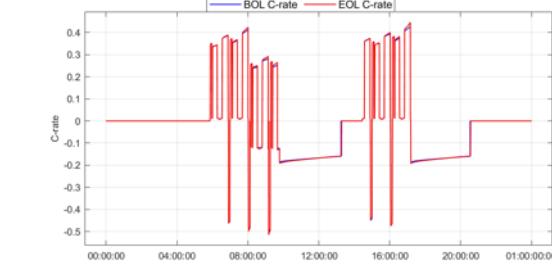
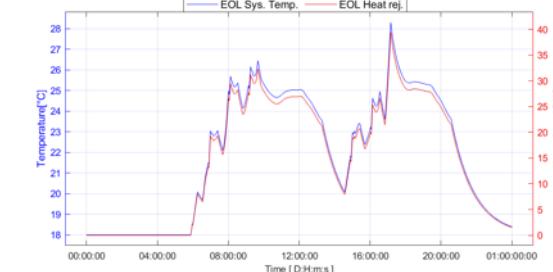
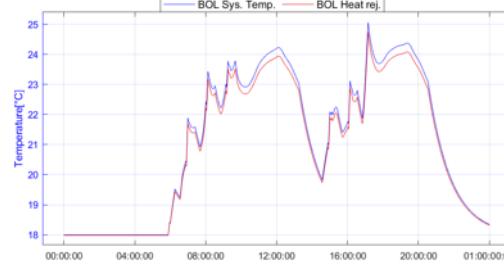
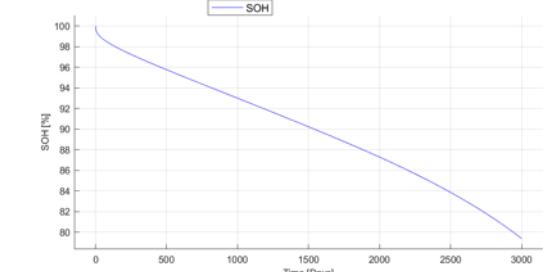
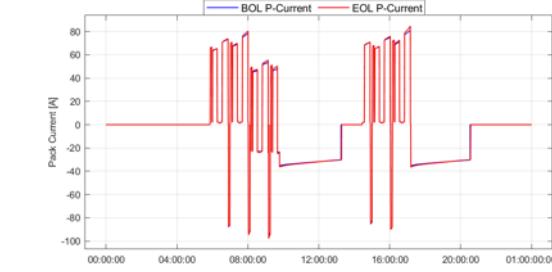
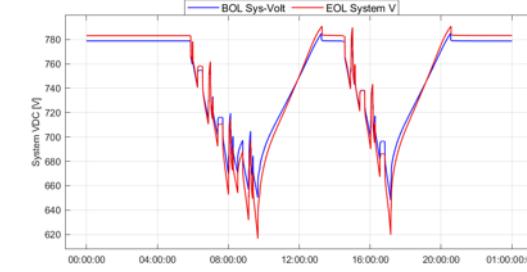
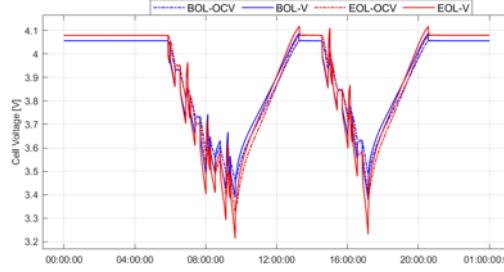
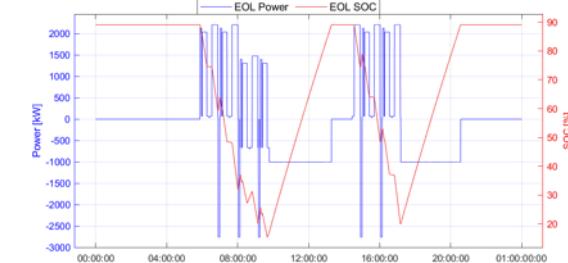
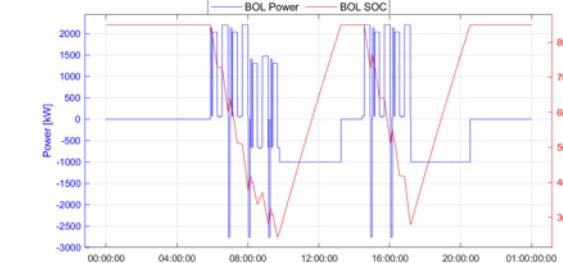
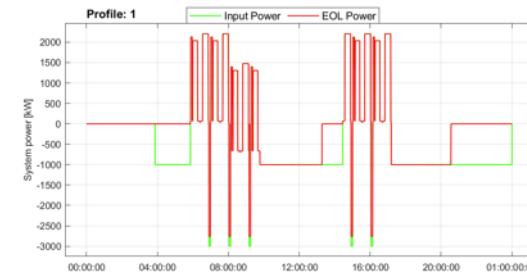
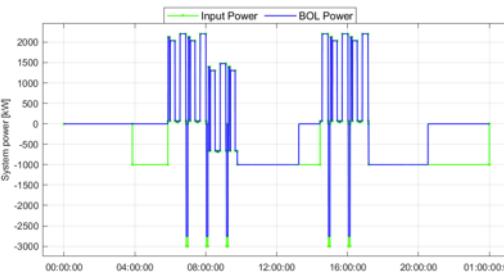
Digital Twin Model

- Load profile can be a simple profile or a combination of multiple profiles in a desired sequence over a 10-year time
- Includes both short-term performance as well as long-term degradation phenomena
- Can be configured for a desired product.
Examples: Corvus Orca, Blue Whale or Dolphin NxtGen ESS



Digital Twin for optimal battery system design

- Accurate profile as an input over 10 years
- Optimal SOC operating range over the time
- Detailed insight into BOL and EOL performances



Digital Twin for battery system

Remaining Useful Life (RUL) estimation

Practical use cases:

- Load profile at the time of battery system sizing was underestimated
- Change of operational route for the vessel
- Onshore charging infrastructure
- Additional operational modes for hybrid vessels

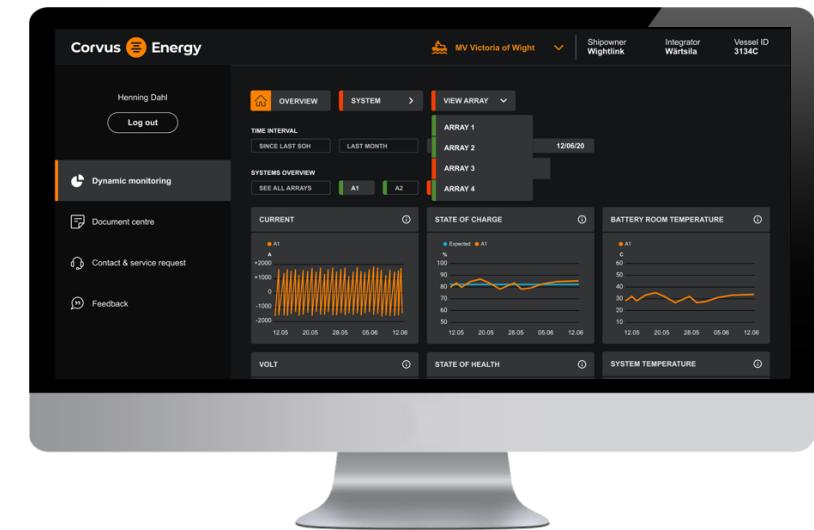
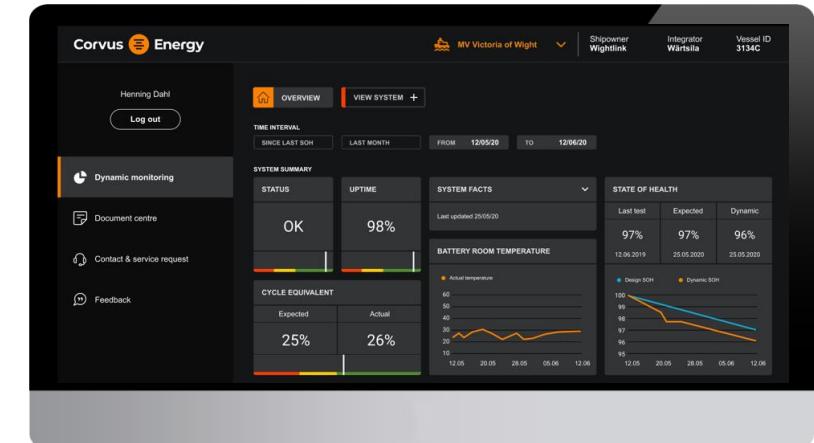
Digital twin can predict the Remaining Useful Life of an existing battery system

- Based on the present SOH
- Future operational conditions

Data Analytics

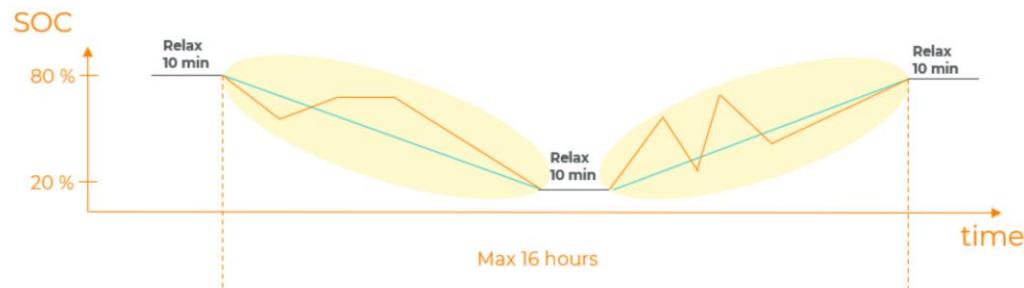
Data from more than 500 Corvus battery systems is logged and stored in the Cloud

- **Average battery system size is ~1MWh**
- **For ~1MWh battery system:**
 - ~1850 cell voltages, cell temperatures, SOCs etc.
 - Pack currents, Ambient temperature
 - Event logs
- **Data sampling rate is ~1sec.**
- **25 detectors continuously monitoring field data for anomalies**
This increases battery safety by reducing downtime and identifying issues before they become safety risks



Digital **State of Health** Testing

Conduct class-required battery system State of Health (SOH) tests digitally, without taking the vessel out of operation.



Advanced Analytics

Key Benefits

- ✓ Saves time and cost
- ✓ Data-backed and DNV-accepted
- ✓ Highly efficient and accurate
- ✓ Makes more frequent testing a viable option to support safety and predictable operation, especially toward the end of system life



Thank you!

Corvus  Energy



NEMOSHIP

MARINE BATTERIES CHARACTERISATION

Pilar Meneses, Cidetec



Testing activities at CID lab

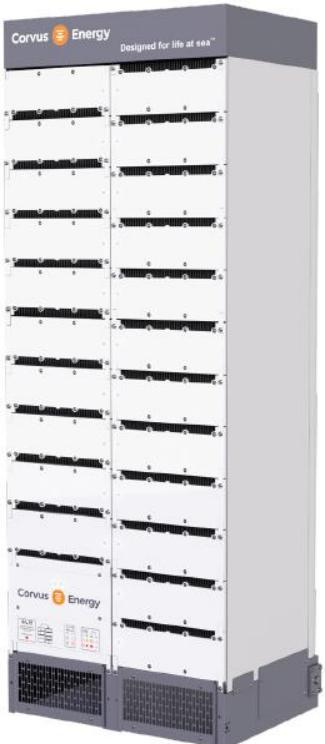
ORCA: (NMC)

DOLPHIN NextGen Energy: (NMC)

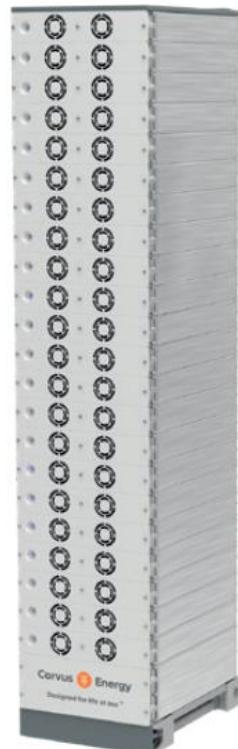
DOLPHIN NextGen Power: (NMC)

<https://corvusenergy.com/products>

Corvus Orca Energy



Corvus Dolphin Energy



Corvus Dolphin Power





The purpose of the heat capacity testing is to **thermally characterize the performance of each cell**.

Thermally characterize the cell in a **controlled, representative, and non-destructive** way, while ensuring measurement accuracy, **safety**, and relevance to real operation.

The heat capacity is one of the intrinsic thermal properties of a battery:

- Represents the amount of energy required to raise one kilogram of battery by one degree and provides the thermal inertia of the battery.
- Determines the system's thermal inertia
- Defines how much MARGIN you have before thermal runaway

Directly affects: Cooling system design, BMS response time Sizing of passive protections.

Heat capacity tests done:

- Get the heat capacity (Cp) in **ramp format** T^a from 20°C to 55°C
- **Temperature rate** of change **sensitivity**: 0.02°C/min
- 3 types of cells (ORCA, DOLPHIN Energy, DOLPHIN Power)
- 2 repetitions min per SOC (10%, 50%, 80%)
- In total 18 tests



By characterizing heat capacity:

- Set **safer operating limits**.
- Improve **early detection and mitigation** strategies for overheating.
- Design better **thermal barriers and cooling systems**.
- This is especially important for high-energy or high-power cells.

The heat is provided by the heater, so the power multiplied by the time variation is the applied energy.

$$CP = \frac{Heat}{m \cdot \Delta T} = \frac{P \cdot \Delta t}{m \cdot \Delta T}$$

Measurements were taken to determine check their good condition.

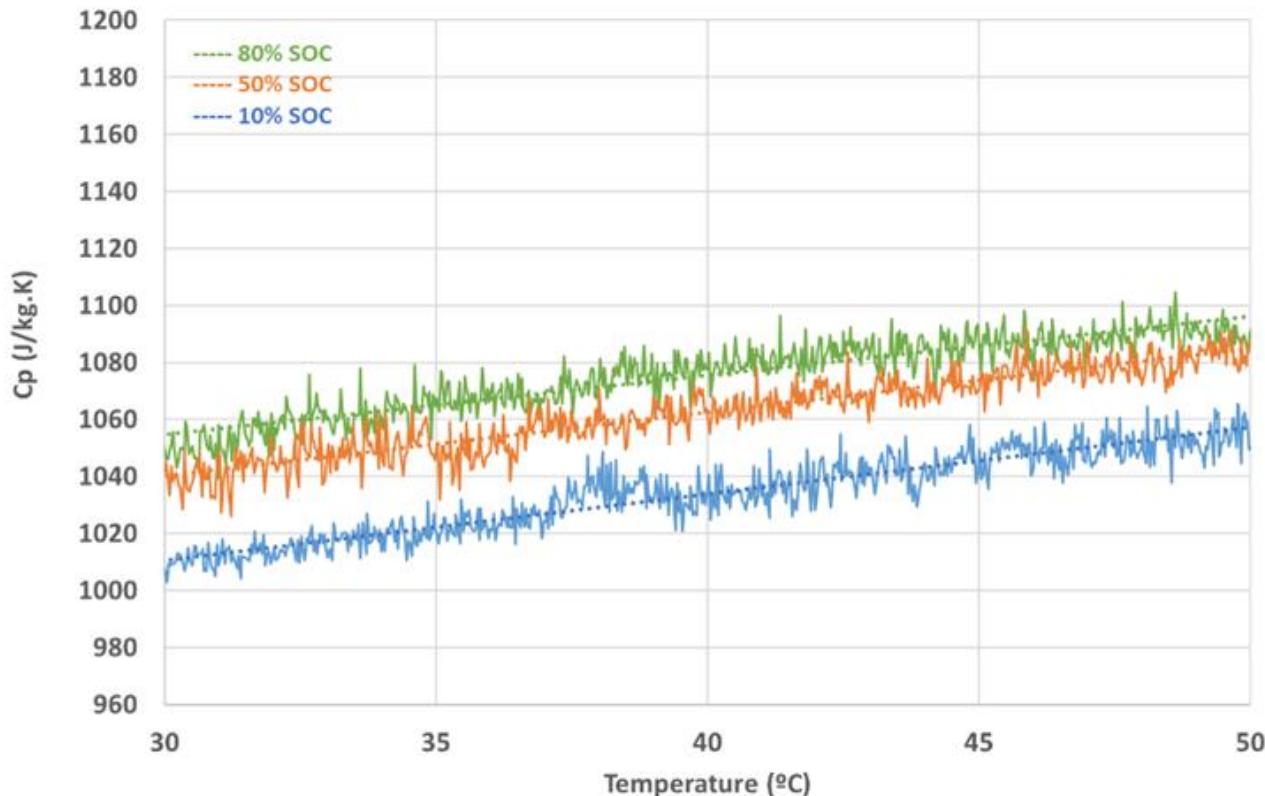
Before starting the setup of CP test, a state of charge (SOC) adjustment is required.

Allows you to:

- Build **reliable thermal models** of the cell.
- Predict temperature rise during fast charge/discharge, faults, or ambient changes.
- Simulate worst-case scenarios instead of relying on assumptions.



ORCA



| SOC | CP average | CP average |
|-----|-----------------|-----------------|
| | Test 1 (J/kg·K) | Test 2 (J/kg·K) |
| 10 | 1034 | 1035 |
| 50 | 1063 | 1064 |
| 80 | 1076 | 1072 |

$$CP (10\% SOC) = 2.3343 \cdot T^a + 940.57 \quad (R^2: 0.87)$$

$$CP (50\% SOC) = 2.2381 \cdot T^a + 973.09 \quad (R^2: 0.86)$$

$$CP (80\% SOC) = 2.0733 \cdot T^a + 992.61 \quad (R^2: 0.83)$$





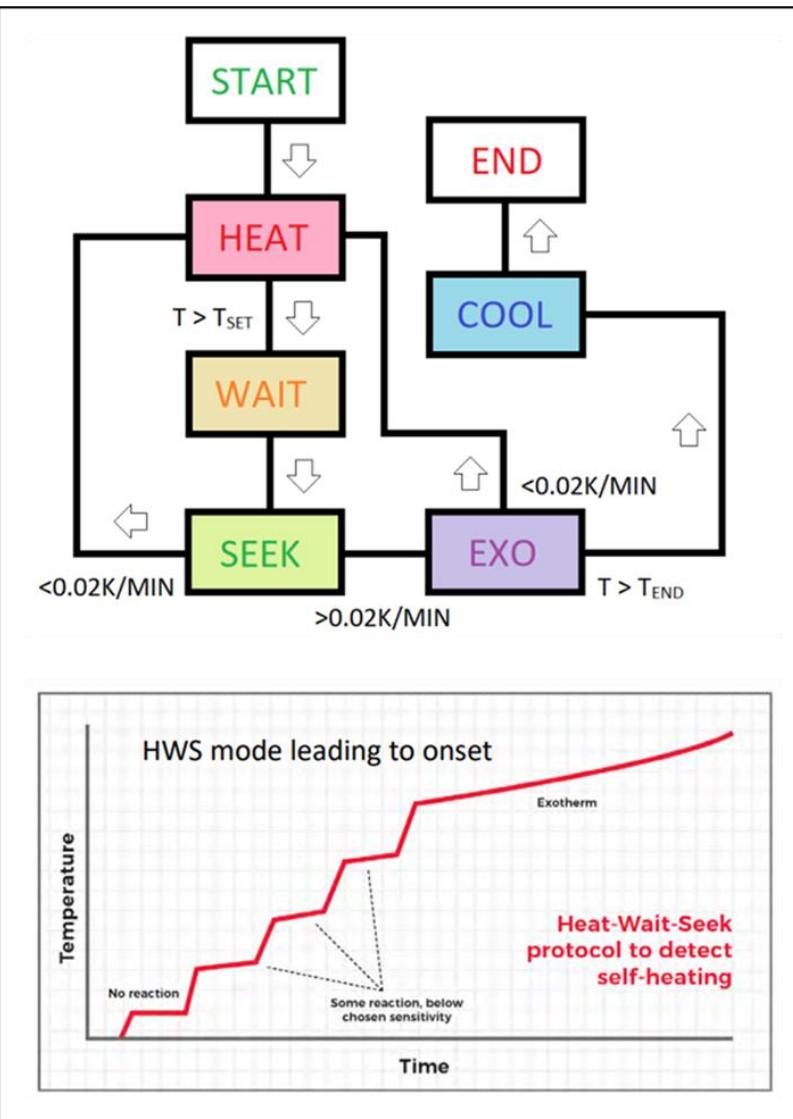
- They characterize the actual battery failure
- They validate the intrinsic safety of the chemistry and internal design
- They assess the risk of propagation between cells and modules
- They define actual thermal limits for the battery management system (BMS) and cooling design
- They support certification and regulatory compliance

TEST PROCEDURE

Thermal Run Away (TRA) tests done:

- 2 samples per type of ORCA cell
- 3 samples per type of DOLPHIN Energy NextGen and DOLPHIN Power NextGen
- At 100% SOC

- Heat-wait-seek mode (HWS) method shall be used
- Initial temperature: 60 °C
- Temperature steps: 5 °C
- Waiting time between steps: 45 min
- Maximum temperature: 305 °C
- Temperature rate of change sensitivity: 0.02 °C./min
- Initial pressure: 1 atm
- Initial SOC: 100%



- The “*Heat-Wait-Seek*” is a measurement mode used in calorimeter devices according to Electric Arc that increase the temperature in the cells.
- The test starts: “*Heat Mode*” by heating up the cell in small temperature steps (5 K).
- At the end of each step, the “*Wait Mode*” is activated to reach thermal equilibrium.
- Then, the system enters “*Seek Mode*”, which seeks the temperature rate of change and ends with two possible modes: “*Exotherm Mode*” or “*Heat Mode*”.
- If the measured temperature rate of change is larger than the onset value (0.02 K/min), which means that **self-heating** of the cell is detected, the system goes into “*Exotherm Mode*”. Thus, it is heating up until a thermal runaway occurs or the chemicals are completely consumed by the exothermic reactions.
- If the temperature rate of change falls below the onset value (0.02 K/min), the system goes back into “*Heat Mode*”.
- If the temperature in “*Heat Mode*” exceeds the maximum temperature value (305 °C), the accelerating rate calorimetric enters “*Cool Mode*”, switches off the heaters and starts to cool down by introducing pressurized air to the chamber.

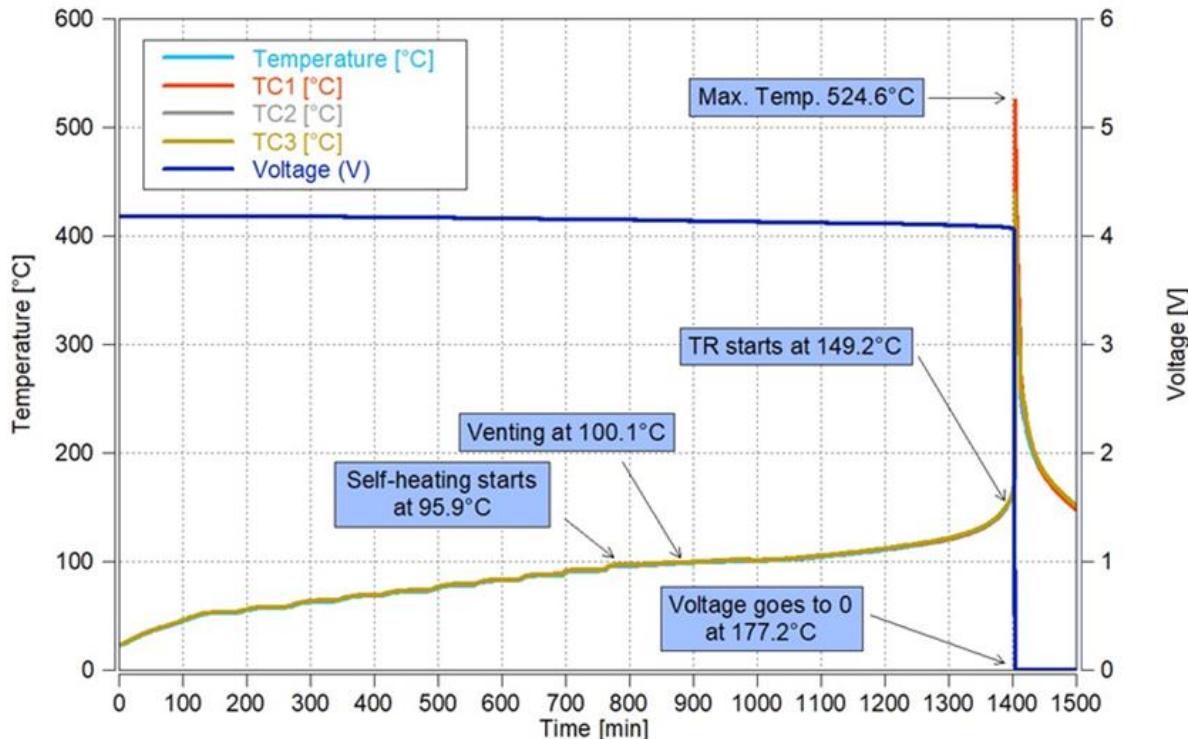


CELLS TESTING – TRA TESTS – ORCA CELLS

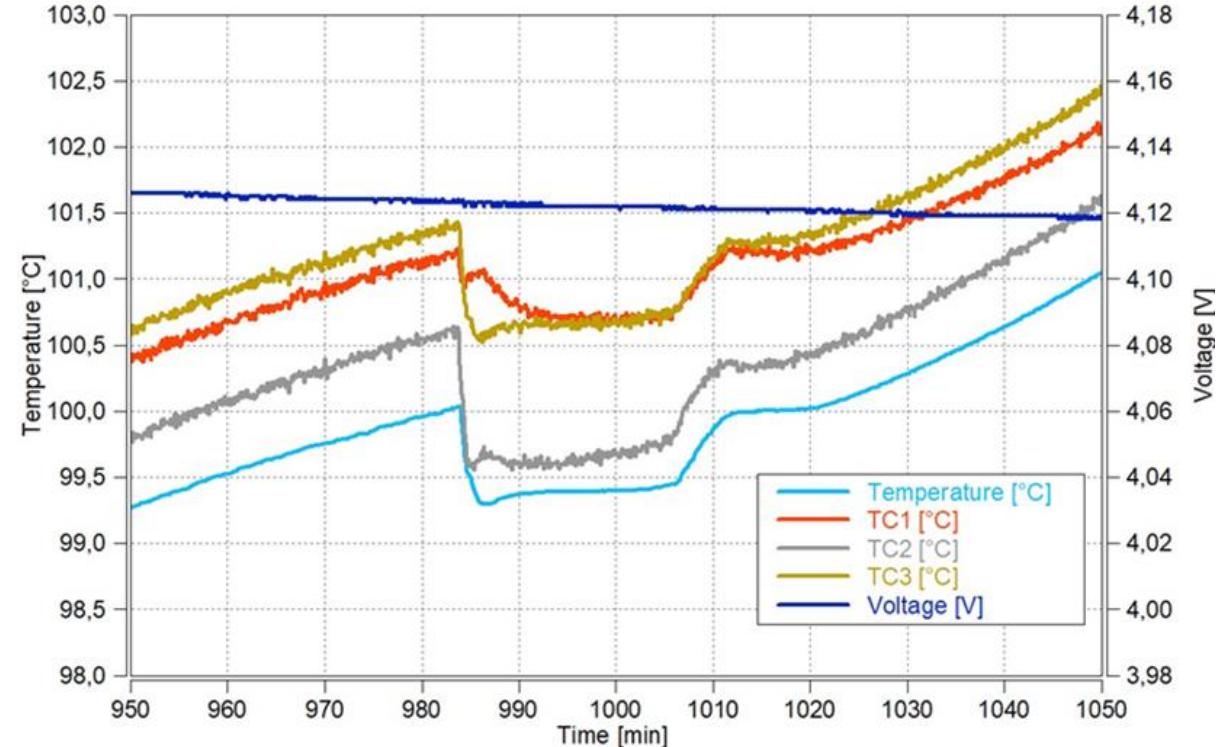


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Orca cell_07 test temperature and voltage plot



Orca cell_07 venting temperature and voltage plot



- The **venting process** is a situation in which the built-up gases in a battery must be released quickly at a specific pressure.
- From that moment onwards, the phenomenon becomes **uncontrollable**, producing **flammable and toxic gases** which in turn increase the internal pressure of the cell.
- This overpressure causes the gases to be released through the pressure relief vents or due to a rupture of the casing, known as venting. During process, there is **little drop in the temperature** of the cell due to a punctual loss in the pressure.

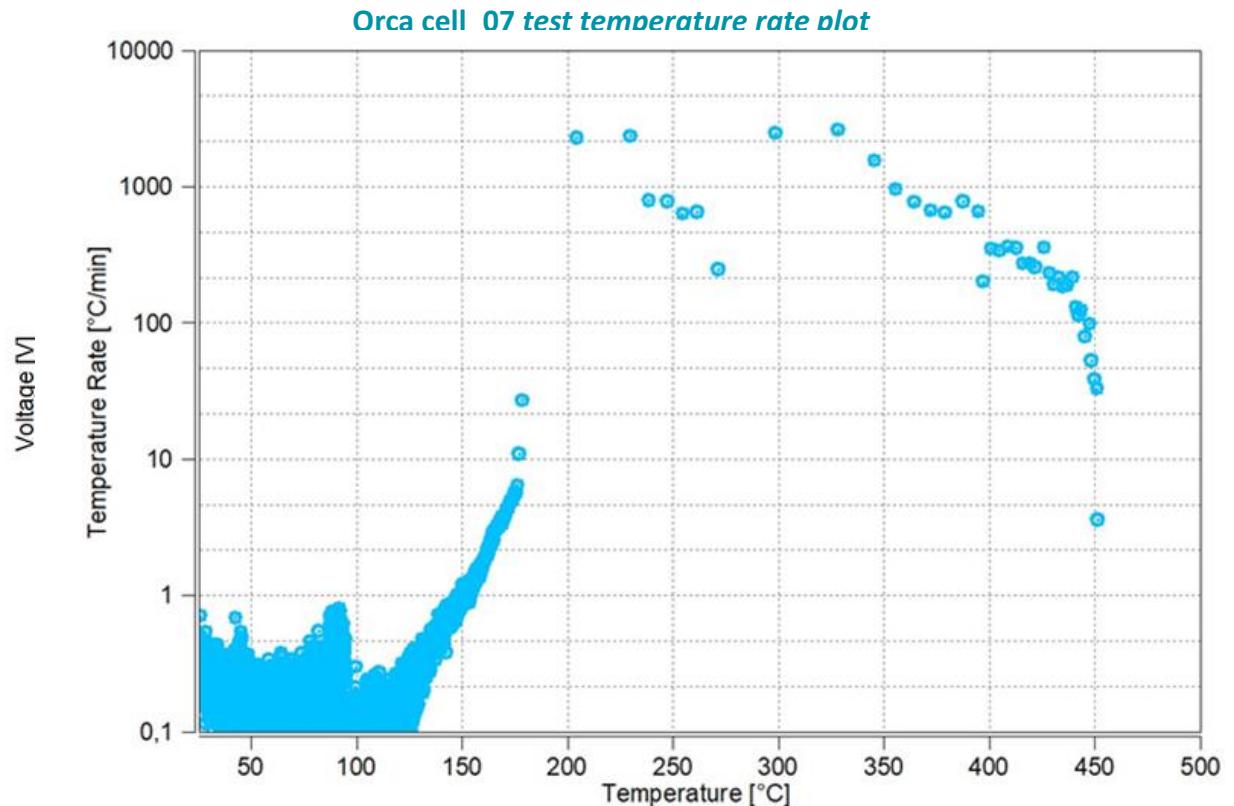
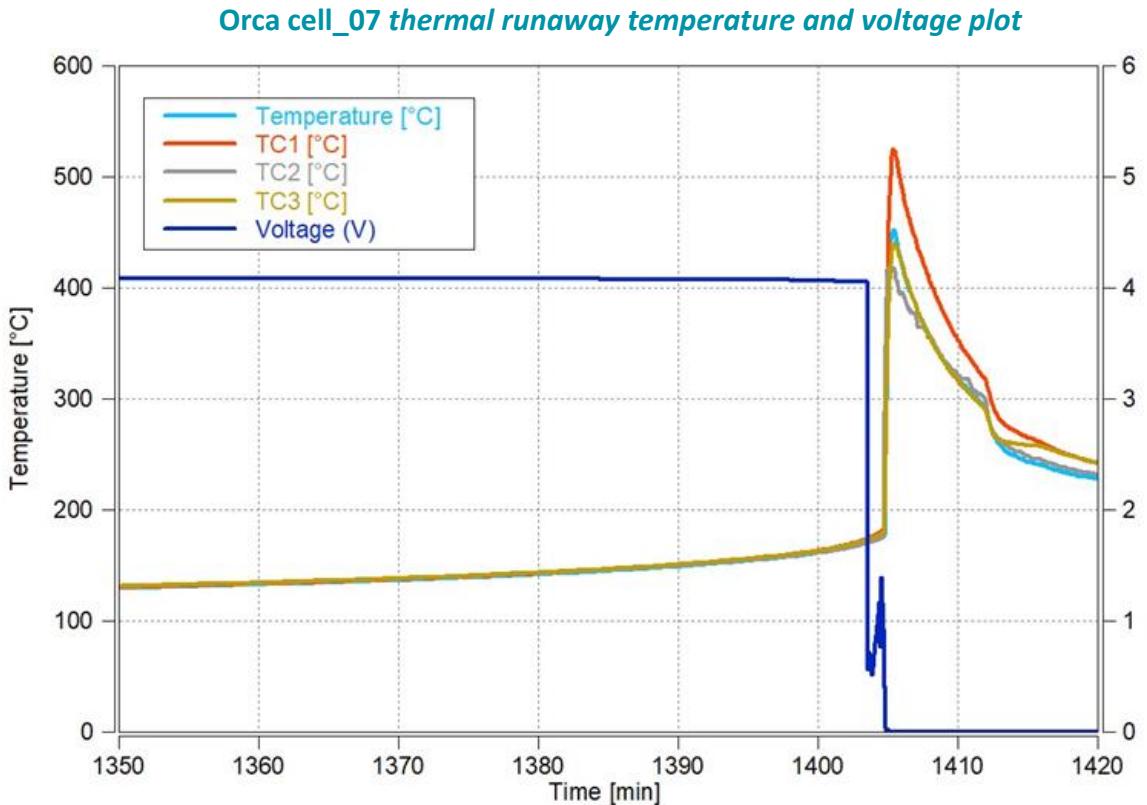


Co-funded by
the European Union

CELLS TESTING – TRA TESTS – ORCA CELLS



NEMOSHIP



- When the **inflammable gases** released come into contact with the outside air, there is a **risk of explosion or fire**.
- Once the thermal runaway has been initiated in a cell, the **phenomenon may propagate** to the other nearby cells forming part of the module and may even affect the whole battery if suitable containment measures are not taken. Propagation is one of the **greatest risks** derived from thermal runaway.



Co-funded by
the European Union



Comparison between cells ORCA_CELL07 and ORCA_CELL08.

| Temperatures [°C] | Initial | Self Heating | Venting | TR | Max T ^a | Max. T ^a rate [°C/min] |
|-------------------|---------|--------------|---------|-------|--------------------|-----------------------------------|
| ORCA_CELL07 | 60.0 | 96.0 | 100.0 | 149.2 | 451.4 | 2601.518 |
| ORCA_CELL08 | 60.0 | 101.2 | 103.0 | 146.9 | 358.3 | 1827.439 |

Tested cells mass loss.

| Mass | Initial [g] | Final [g] | Mass loss [%] |
|-------------|-------------|-----------|---------------|
| ORCA_CELL07 | 1157.85 | 770.37 | 33.47 |
| ORCA_CELL08 | 1155.68 | 769.36 | 33.43 |

The tests have been carried out successfully. The behaviour of the cells has been as expected and the data collected gives enough information to understand it.

- Both cells had similar thermal behaviour and mass loss.



- Corvus battery products have been tested without any problem, and the results were correct and expected.
- The test results from the cells **are useful to extract the model parameters** required to build a detailed equivalent circuit models for the cells.
- It can contribute to obtain a good performance of the **specific heat capacity** of Corvus batteries which is an input for the thermal behaviour of the batteries: the capacitive response.
- Additionally, thermal runaway tests were also carried out in the calorimeter for calculating the **characteristic venting rate**.
- The results from thermal runaway tests are important to quantify the **critical safety limits** of the cells.



Q&A FOR:

- **Marine batteries safety / Lars Petter Larsen, Corvus**
- **Marine batteries characterisation / Pilar Meneses, Cidetec**



NEMOSHIP

COFFEE BREAK
10:20 TO 10:35



NEMOSHIP

INNOVATION 1: HETEROGENEOUS BATTERY SYSTEMS AND DEDICATED CONTROL

**Sizing a heterogeneous battery system to fit the vessel
needs**

Vincent Philippoteau, CEA



CONTENTS

1. Introduction
2. Methodology
 - Data Collection
 - Power Profile
 - HE and HP sizing
3. Conclusions and perspectives





Sizing a heterogeneous battery system for an offshore vessel: methodology and application

Install a 1 MWh heterogeneous energy storage system on a vessel, consisting of:

- **A High Energy (HE) battery** (primarily providing continuous nominal power)
- **A High Power (HP) battery** (with a higher C-rate)

Ensure the battery system meets the vessel's energy requirements.

Extend the lifetime of the battery system:

- The hybrid topology aims to reduce high current stress on the HE battery, leading to a longer lifespan when properly managed.



Conventional Sizing

Based on specifications, the power and capacity of the battery system can be determined

Example: The battery system must supply 2.2 MW and have a capacity of 1 MWh

Optimal Sizing

Objective: Achieve an optimal sizing to avoid under-sizing or over-sizing based on specifications

Requirement:

- Use real-world data to ensure accuracy
- For instance, when HP batteries handle high-frequency currents, time-series data is essential

Methodology:

- Collect real-world operational data
- Define a power profile
- Determine the sizes of HP and HE batteries based on the power profile



Data collection

Power profile

HE and HP sizing



Normand Ferking

AHTS (Anchor Handling Tug Supply) vessel

gross tonnage : 7934 metric tons

Length Overall : 90m

Generators : 15.2 MW

(will be replaced by **Normand DROTT**, which has the same size and missions)

| Vessel operating mode | BESS mode | Comment |
|-----------------------|---|--|
| Port | Shore power with peak-shaving Full electric | To be able to use shore power for hotel load and BESS to take any power demand exceeding the shore power discharge. Full electric for short port changes. |
| Dynamic Positioning | Spinning reserve | To reduce the number of engines in use while on DP close to offshore installation. |
| DP-Standby | Spinning reserve and Full electric | To reduce the use of engine and increase efficiency by doing full electric cycles charged by one engine activation.. |
| Transit Eco | Peak-shaving and Full electric | Peak-shaving on the load in transit over longer distance (exceeding the full electric part). Full electric in and out of port and maneuvering. |
| Transit | Peak-shaving | Peak shaving on the engine load while in transit to keep the engines at a better load. |
| Anchor handling | Spinning reserve and “beast mode” | To be able to have BESS as backup and in some cases reduce the engines needed. Additionally, to test if the battery can increase the bollard pull of the vessel. |
| Towing | Peak-shaving | Peak-shaving on the engines running while towing. |

METHODOLOGY



NEMOSHIP



Data Source



Fuel consumption, in different modes
1 point per day



Normand Ferking



Normand Ocean



Battery data (currents, voltages,
temperatures, etc.)
1 point /s



(But not same usage as Normand
Ferking)



(No battery installed)

(will be replaced by Normand DROTT, which has similar size and missions)

METHODOLOGY



NEMOSHIP

Data collection

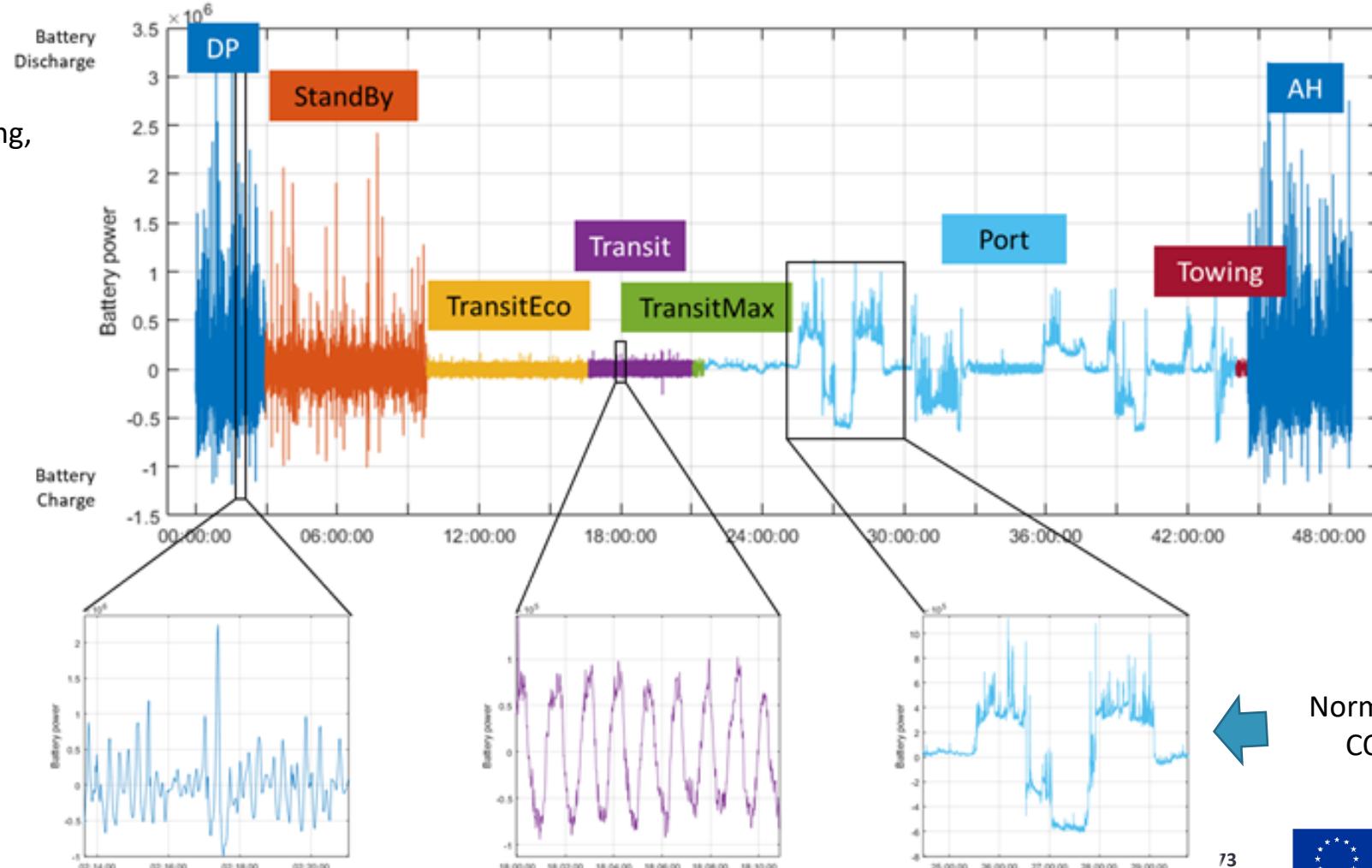
Power profile

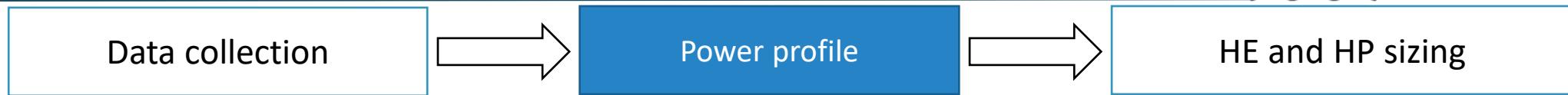
HE and HP sizing

From the MARESS data of Normand Ferking, we built a representative powerprofile. Times series data came from the 1MWh battery installed on the Normand Ocean.

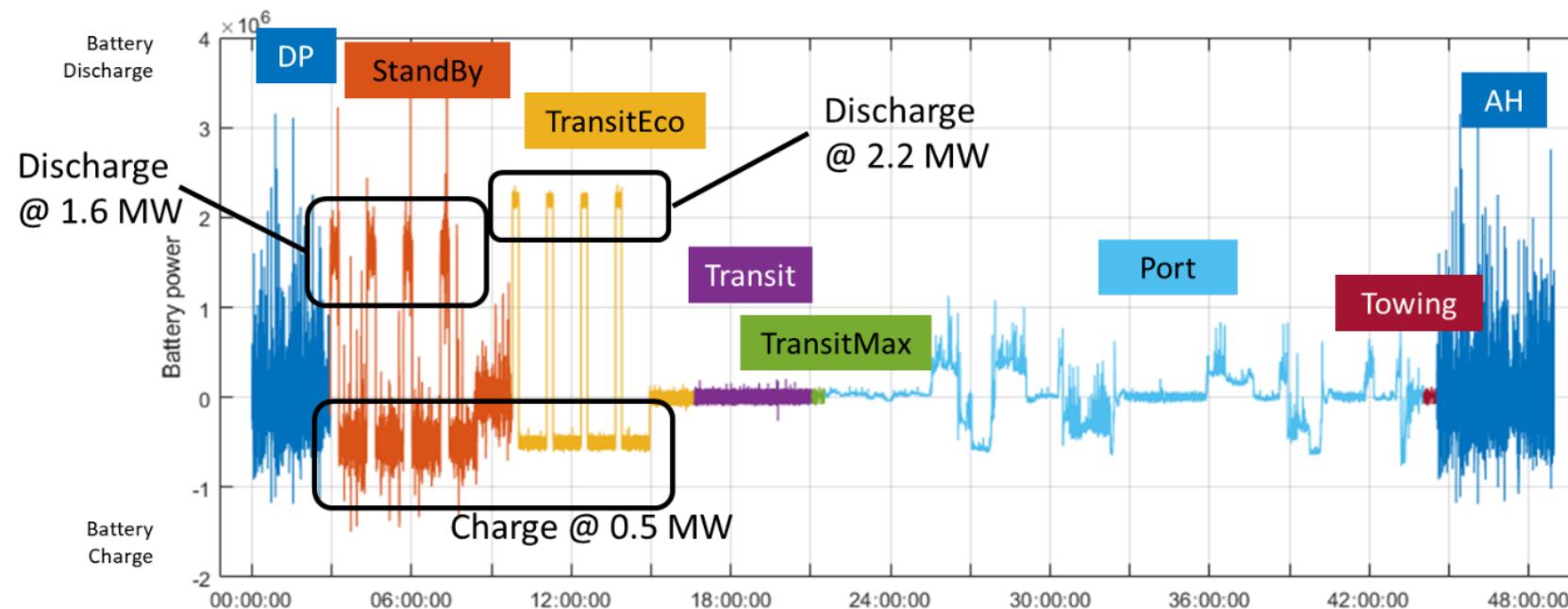
| Vessel operating mode | Share of the time (over 363 days) |
|------------------------------|-----------------------------------|
| Port | 46% |
| DP | 6% |
| DP-Standby | 14% |
| Transit (eco, normal or max) | 24% |
| Anchor handling and towing | 11% |

Normand Ferking
MARESS Data





We added full electric modes (@1.6 and 2.2 MW), in order to simulate « Full electric » mode



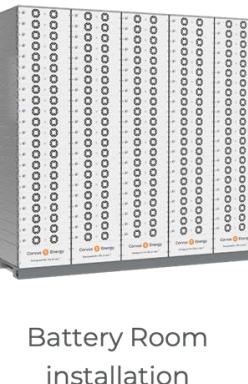
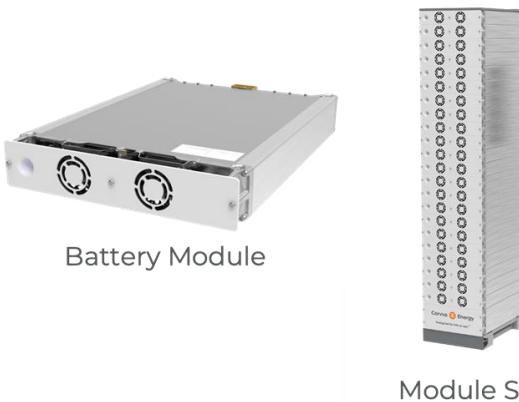


Data collection

Power profile

HE and HP sizing

High Energy battery



Technical Specifications | Corvus Dolphin Energy

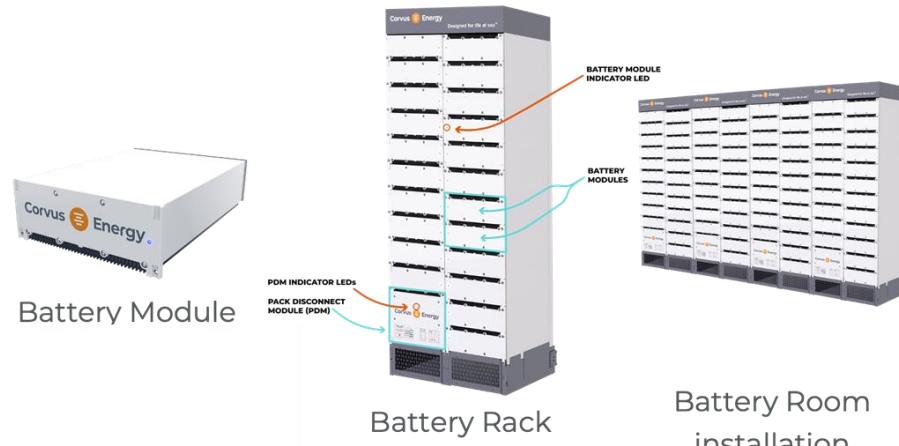
Performance Specifications

| | |
|--|----------------------------|
| C-Rate - Peak (Discharge / Charge) | 1,0C / 1,0C for 10 seconds |
| C-Rate - Continuous (Discharge / Charge) | 0,5C / 0,5C |

System Specifications

| | |
|---------------------------------------|------------------------------|
| Single Module Size / Increments | 8,3 kWh / 50 VDC |
| Single Pack Range | 116 - 199 kWh / 504-1195 VDC |
| Max Gravimetric Density - Pack | 168 Wh/kg 5,96 kg/kWh |
| Max Volumetric Density - Pack | 217 Wh/l |

High Power battery



Technical Specifications | Corvus Orca Energy

Performance Specifications

| | |
|--|-------------------------|
| C-Rate - Peak (Discharge / Charge) | Project Specific Values |
| C-Rate - Continuous (Discharge / Charge) | Up to 3C / Up to 3C |

System Specifications

| | |
|---------------------------------------|---------------------------|
| Single Module Size / Increments | 5,6 kWh / 50 VDC |
| Single Pack Range | 38-136 kWh / 350-1200 VDC |
| Max Gravimetric Density - Pack | 77 Wh/kg 13 kg/kWh |
| Max Volumetric Density - Pack | 88 Wh/l |

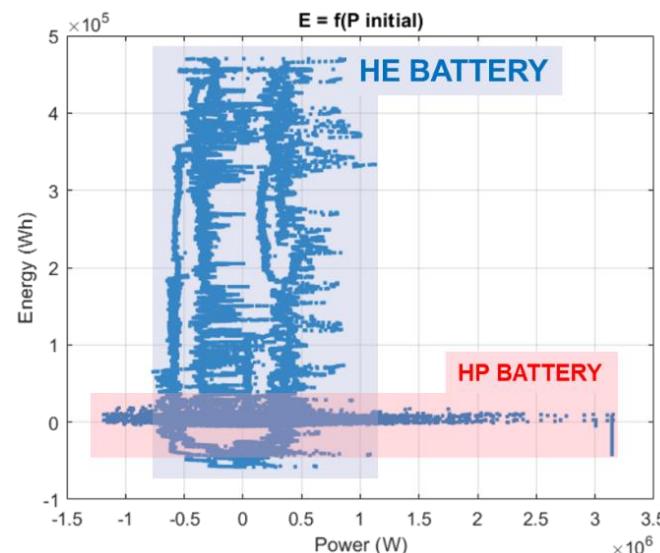


Data collection

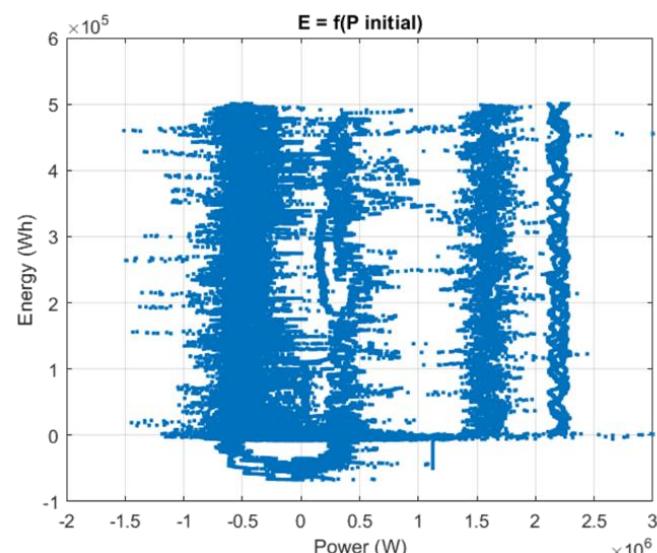
Power profile

HE and HP sizing

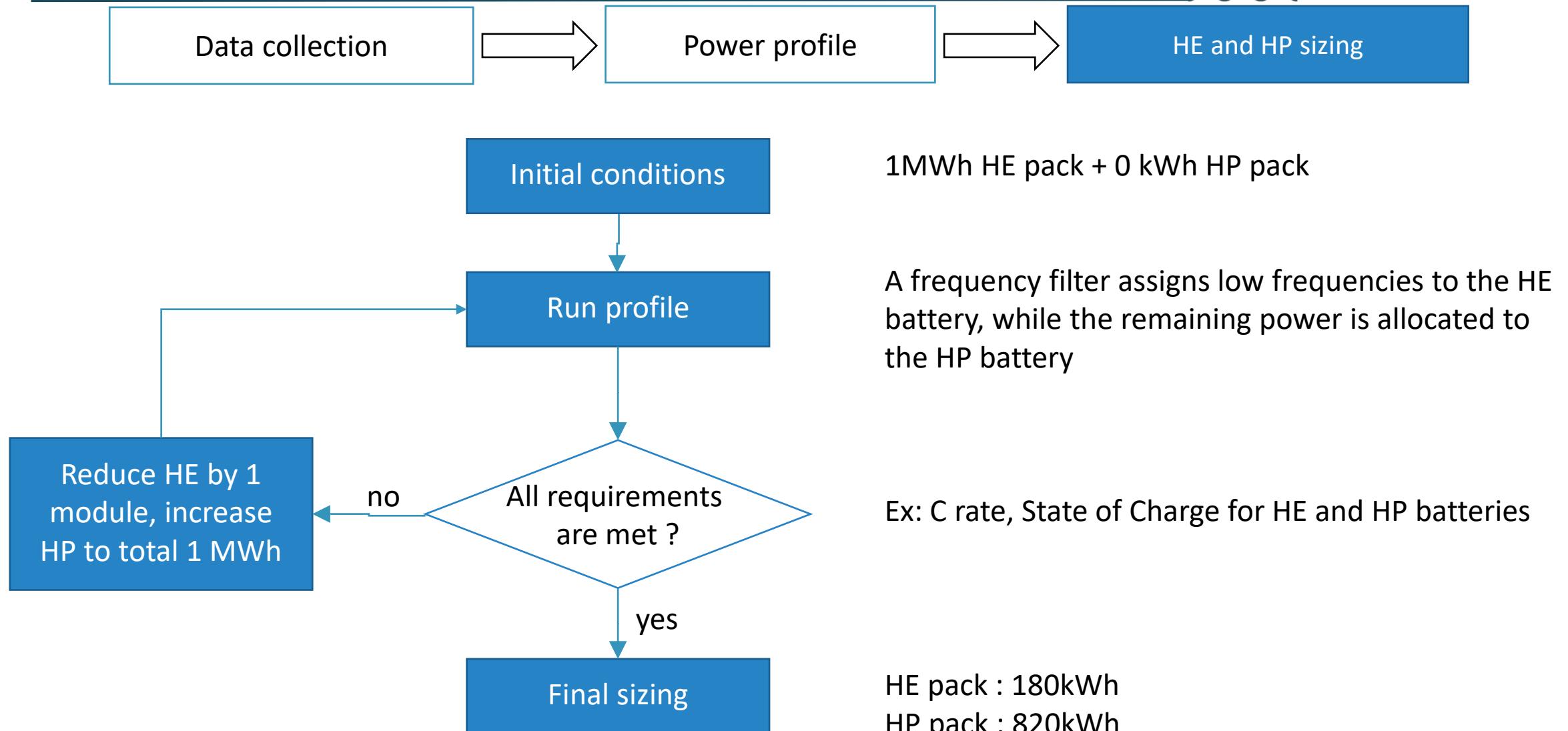
Energy VS Power diagram



Without Full Electric modes



With Full Electric modes
(required in NEMOSHIP project)





This study proposes a methodology for sizing heterogeneous battery systems, applied to an offshore vessel.

Key results:

- **Optimal HE/HP share:** 82% HP, 18% HE.
- **Constraints:** 1 MWh, 3 MW, Lithium-ion NMC/graphite with differing C rates.

This study could be enhanced by revisiting certain assumptions :

- **Scalability:** Increasing capacity to 5–6 MWh enables HE batteries to handle full power (3 MW), improving control flexibility.
- **Battery Technologies for HP Pack:** Options include LTO (10–20C, ~20,000 cycles), supercapacitors (up to 10,000C but low energy density), or high-power LFP (up to 10C, ~6,000 cycles).
- **Ageing Considerations:** HE and HP ageing depends on power-sharing strategies; HP packs (82% of BESS) may determine system lifespan.
- **Safety/Regulatory Requirements:** Must meet classification standards.
- **Cost, Volume, Weight:** HP batteries are costlier and less energy-dense; trade-offs between power, energy, cost, and space must be assessed.
- **Electrical Architecture:** Explore options like parallel battery packs with dedicated converters. Consider trade-offs between cost, losses, flexibility, and compatibility with ship systems.



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Paper available on NEMOSHIP website: <https://nemoship.eu/results/>





INNOVATION 1: HETEROGENEOUS BATTERY SYSTEMS AND DEDICATED CONTROL

Control solution developed for increased BESS lifetime
(BPMS)

Clément Retière, CEA



NEMOSHIP

BPMS ALGORITHM DESCRIPTION



Dolphin Nxt Gen ESS - Energy

Low C-rate for slow charge and discharge

0.5C RMS / 1.0C for 10 seconds

In NEMOSHIP:

33% of battery pack

361kWh

HE



Orca ESS

Higher C-rate for faster charge and discharge

Up to 3C

In NEMOSHIP:

67% of battery pack

745kWh

HP

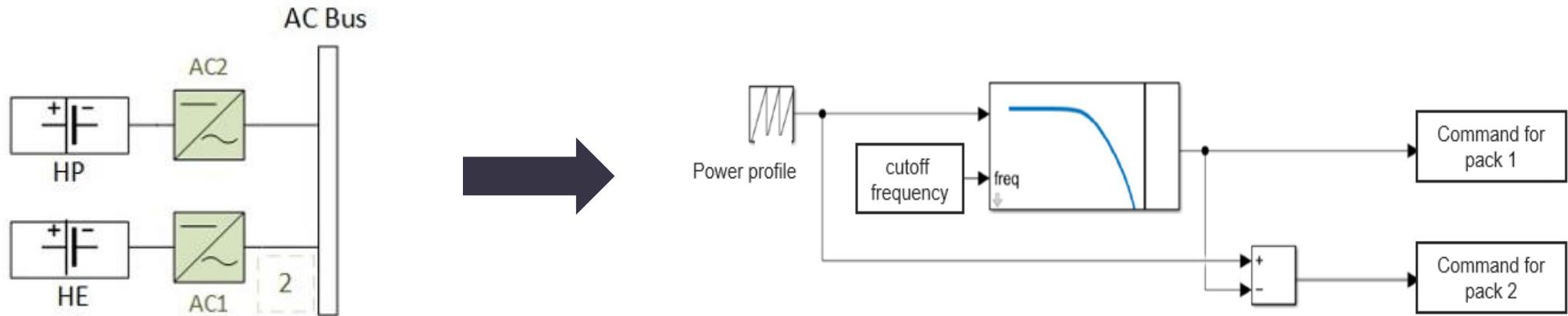
1.1 MWh heterogeneous system installed on vessel Normand Drott



BPMS MAIN FUNCTION: POWER SPLIT



NEMOSHIP

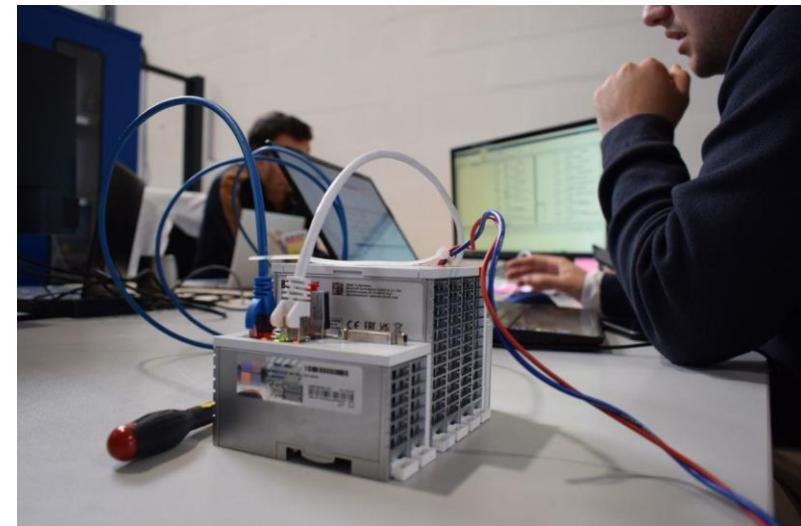


- PMS and EMS define power to be provided by overall BESS on AC bus.
- BPMS strategy splits this power request into two power setpoints for HE and HP ESS **based on a low pass filter**.
- This kind of filter is basically set with a parameter named Tau, changing the frequency value of the filter.



Goal : Improve the robustness of the algorithm and limit battery aging

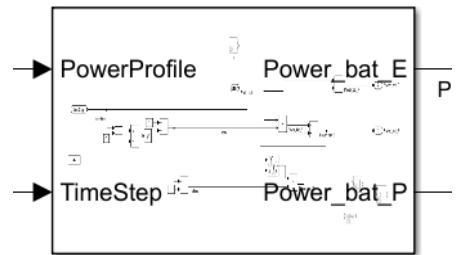
- **Filter behavior:** Change filter by a critically damped second-order filter. This helps better suppress high-frequency components and **allows tuning gain and time constant** for greater flexibility in adjusting the power distribution.
- **Anti interpack current function:** Power sign changes are not instantly followed in the HE battery power setpoint due to the inertia of the filtering. This phenomenon leads to losses in the converters and accelerated battery aging without providing any useful service -> **Filter reset and slope**.
- **Anti-drift SOC function:** Control loop based on the average SOC value of the HP battery to compensate HE SOC battery from drifting
- **SOC limitation:** Implemented SOC limit for the HP battery



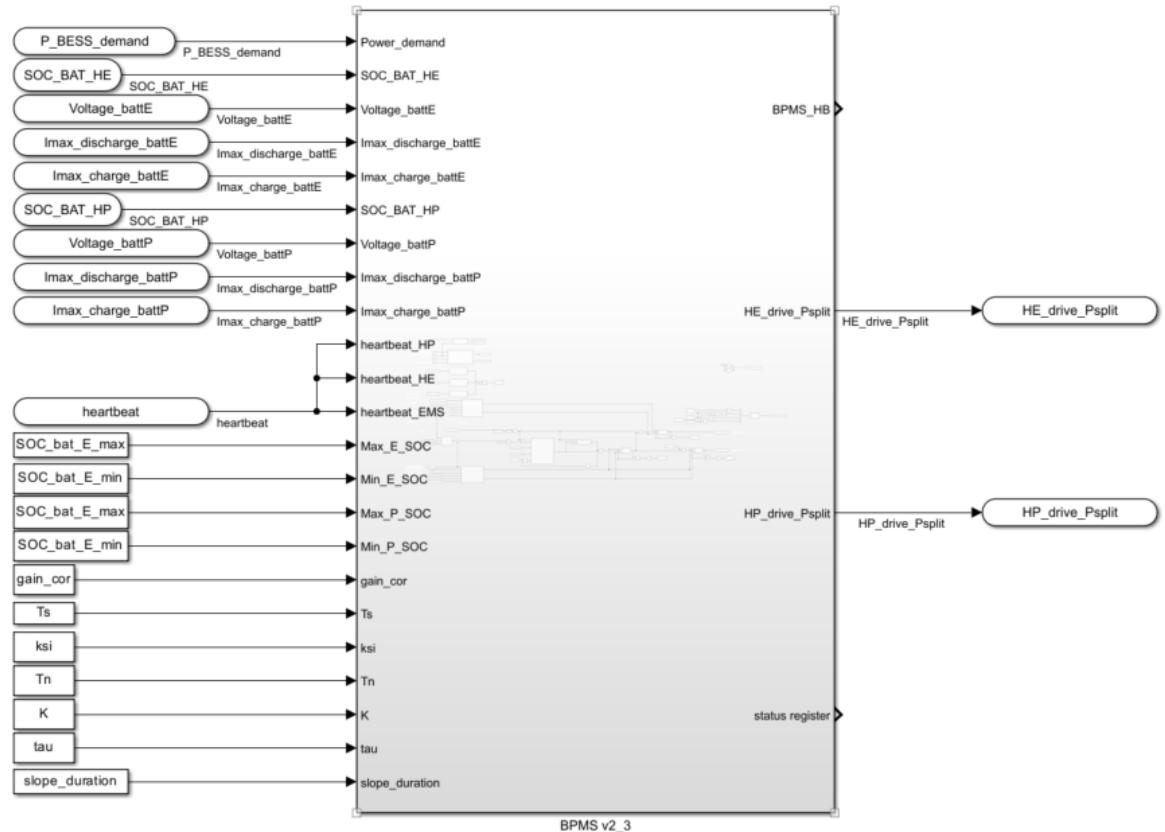
BPMS INPUTS/OUTPUTS



NEMOSHIP



V1



V2



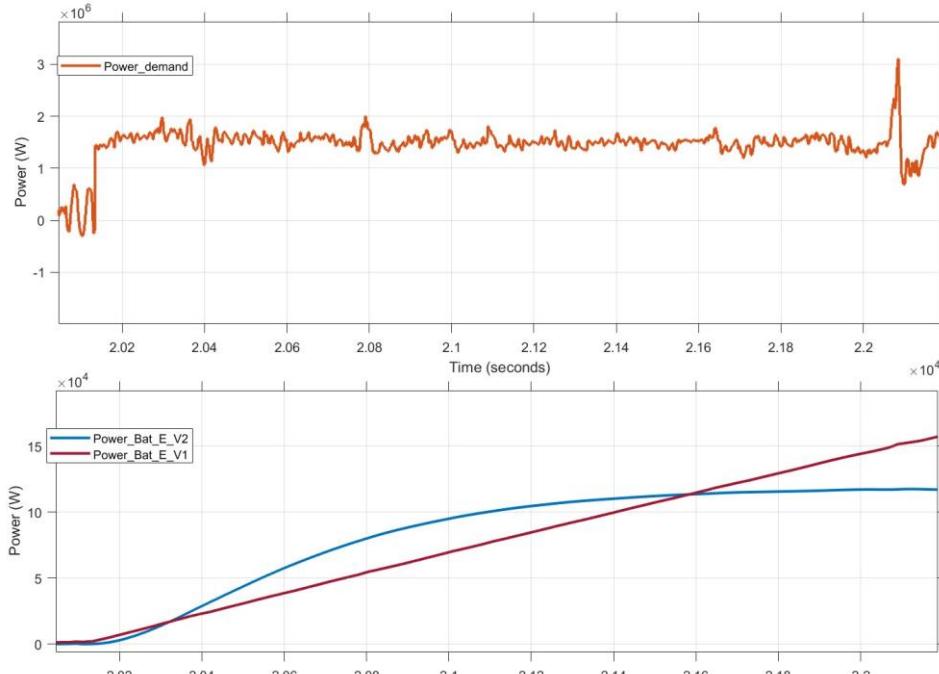
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HIL VALIDATION RESULTS

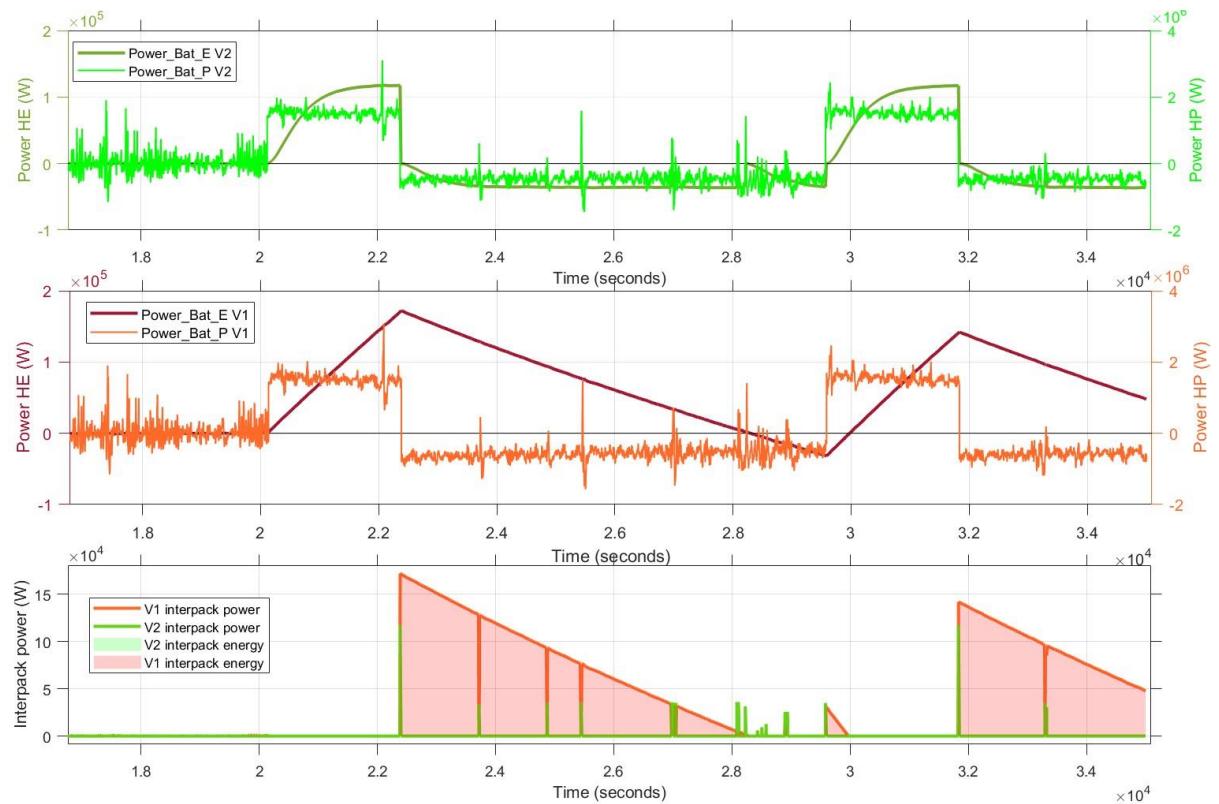


NEMOSHIP

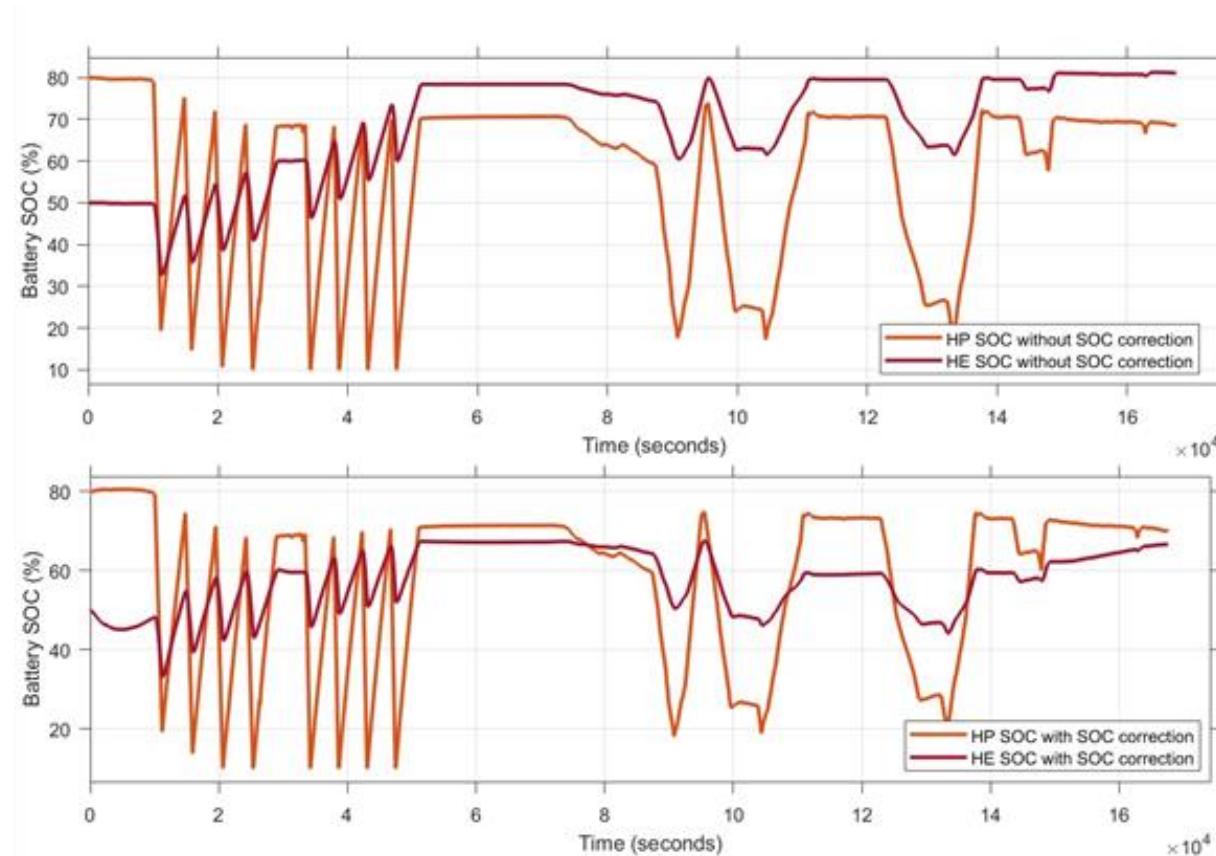
Filter behavior: HE battery contributes its share of power during constant charge or discharge phases while rejecting high-frequency disturbances, which are handled by the HP battery



Anti interpack current function: a filter reset is triggered upon a sign change. To prevent abrupt transitions and frequent unintended resets, a smooth slope decrease is applied to the HE battery's power setpoint



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Expected gains:

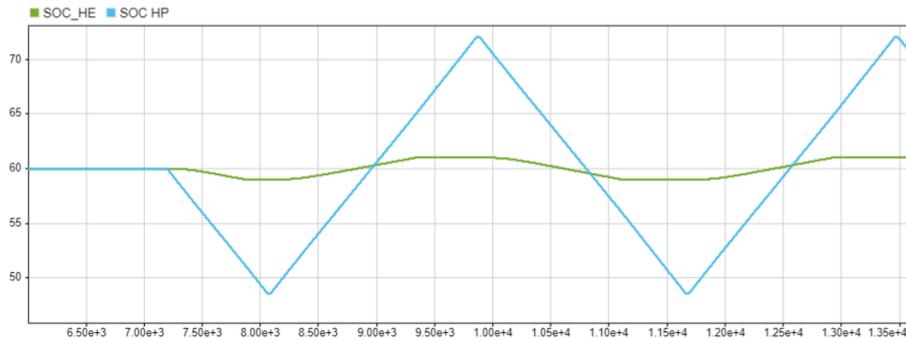
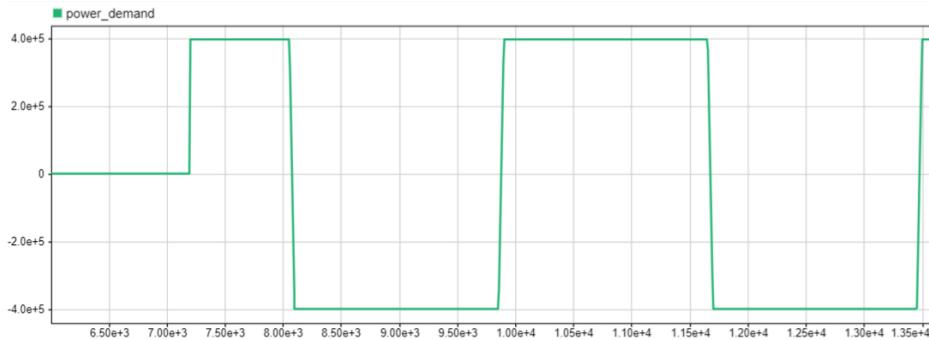
- Less abrupt changes in battery current → extended HE battery lifetime
- Tracking of HP battery SOC → increase available power
- Use of a second order filter → Optimize use of the HE battery for low frequency demand

HIL VALIDATION RESULTS

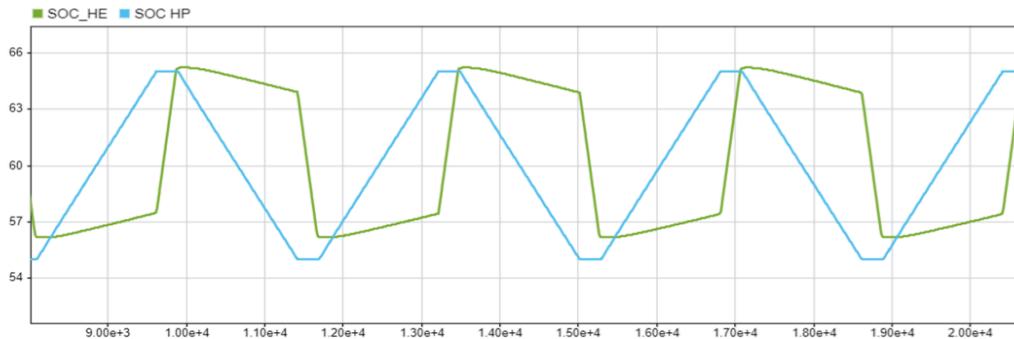


NEMOSHIP

SOC limitation functions have been implemented on both HE and HP batteries. By restricting the SOC variation range, substantial gains in battery lifetime can be achieved. However, this limitation reduces battery availability, and a compromise must be found to best meet these criteria.



State-of-charge (SOC) limitation on the HE battery



SOC limitation on the HP battery, there is a transfer of charge to the HE battery



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IMPACT OF BPMS VERSIONS ON BESS LIFETIME



BPMS

The NEMOSHIP tool evaluates two energy management strategies: V1 and V2, with various parameter sets

High Power (HP) Batteries

Designed for rapid discharge and charge cycles, ideal for dynamic maritime applications

High Energy (HE) Batteries

Optimized for sustained energy delivery, suitable for longer voyages and continuous operations

EOL

The end-of-life (EoL) is defined as 80% usable capacity, based on a weekly repeated 2-day power profile.

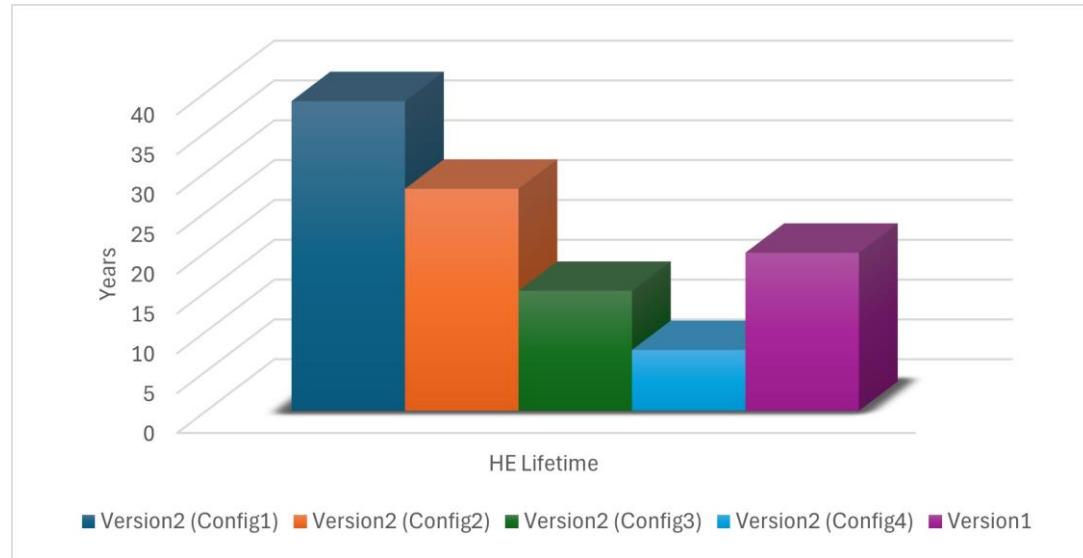
What impacts lifetime?

- Higher DoD per cycle accelerates degradation.
- Fast charging and high power demand increase internal stress.
- Frequent full cycles shorten lifespan.
- Smart power allocation and peak-shaving reduce stress on cells.

BATTERY LIFETIME ANALYSIS THROUGH BPMS VERSIONS



NEMOSHIP

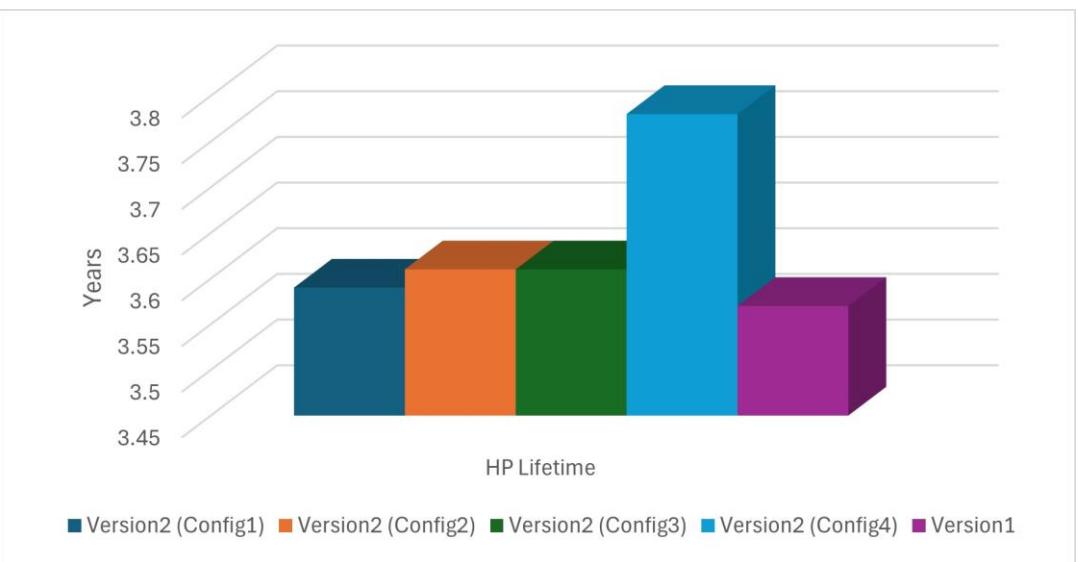


High Energy Battery estimated lifetime

- Around 50% improvement (best case in V2 compared to V1)
- Parameters in BPMS-V2-Config4 offer best trade-off between durability and performance.
- Both battery types benefit from context-specific parameter tuning.

- Around 7% improvement (best case in V2 compared to V1)

High Power Battery estimated lifetime



EFFICIENT POWER ELECTRONICS,
POWERTRAIN & ENERGY SOLUTIONS
RESEARCH GROUP



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- The lifetime assessment is primarily designed to offer a consistent and robust basis for **comparing different BPMS versions**, parameter selections, and energy-sharing strategies, rather than focusing on absolute lifetime predictions.
- Results highlight how **SoC management, cycle depth, and power allocation** strongly influence battery wear in marine profiles.
- V2 also enables synchronized HP/HE replacement cycles (e.g., 2× HP per 1× HE), simplifying maintenance planning.
- Insights support **design choices, parameter tuning, and future EMS development** toward durability-focused strategies.



NEMOSHIP

INNOVATION 1: HETEROGENEOUS BATTERY SYSTEMS AND DEDICATED CONTROL

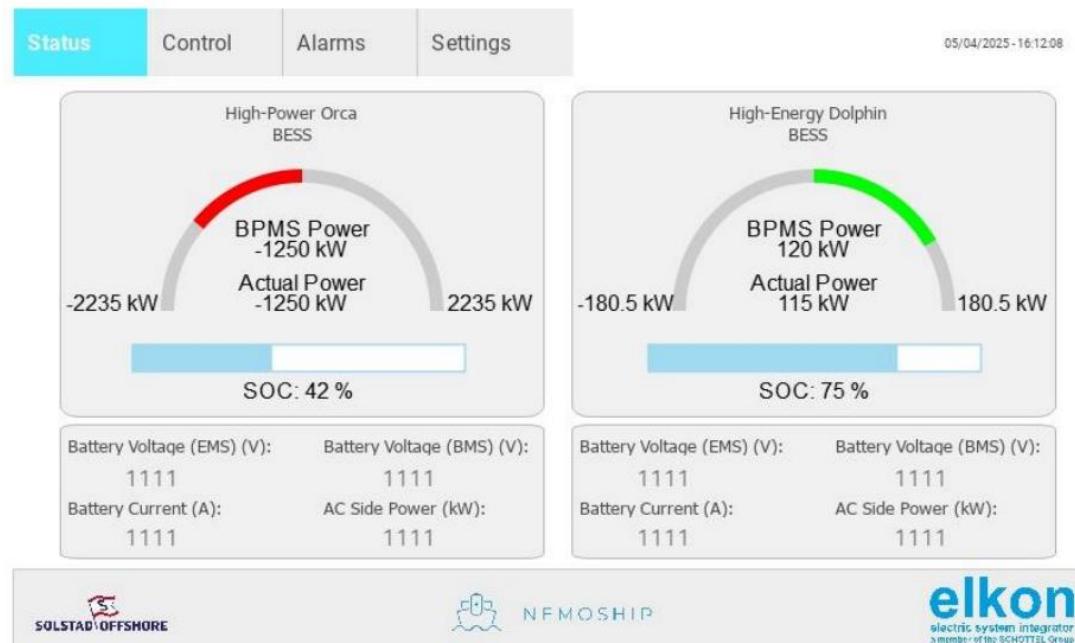
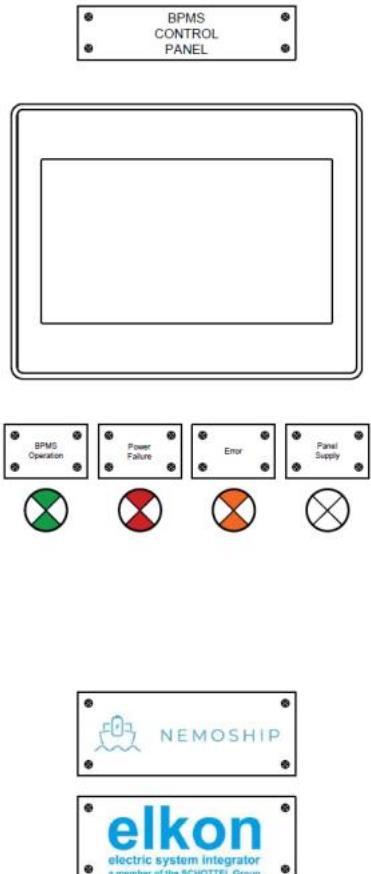
Control solution developed for increased BESS lifetime
(BPMS) - Deployment

Mert Can Çelik, Elkon

BPMS PANEL & INTERFACE



NEMOSHIP



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BPMs PANEL & INTERFACE



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Status **Control** Alarms Settings

05/04/2025-16:23:39

| Tau | Lower Limit SOC | Higher Limit SOC |
|-----|--------------------|---------------------|
| 0 | 0 | 0 |

Update Tau **Update Lower Limit** **Update Upper Limit**

Status Control **Alarms** Settings

05/04/2025-16:15:13

Active Alarms

| Select | Name | State | Time | Description |
|--------------------------|-----------------------|-------------------------|---------------------|-----------------------------------|
| <input type="checkbox"/> | Power Supply Failure | Not Triggered Not Acked | 04/05/25 - 16:14:24 | Cabinet supply voltage is missing |
| <input type="checkbox"/> | Ethernet Switch Alarm | Triggered Not Acked | 04/05/25 - 16:14:30 | Communication cable is unplugged |

Hide Not Triggered

Ack

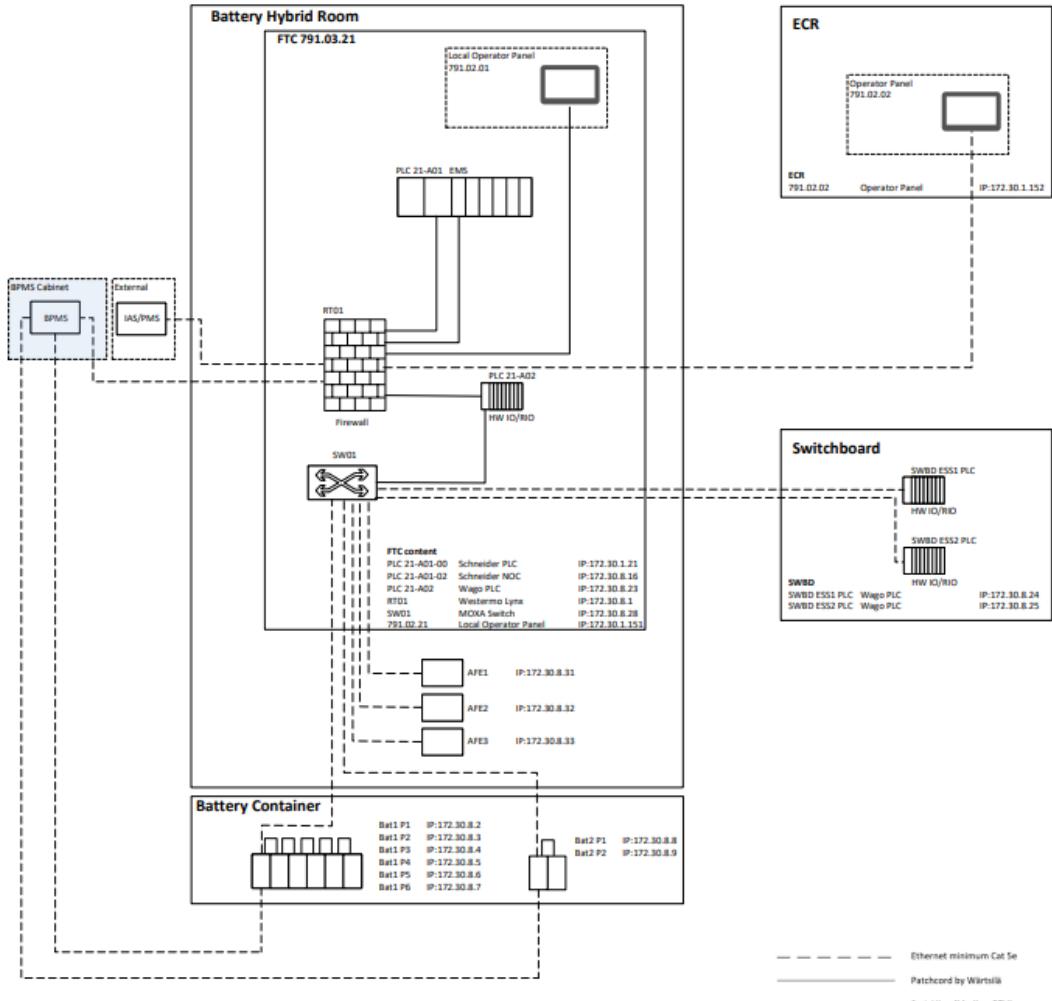


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COMMUNICATION SYSTEM



NEMOSHIP

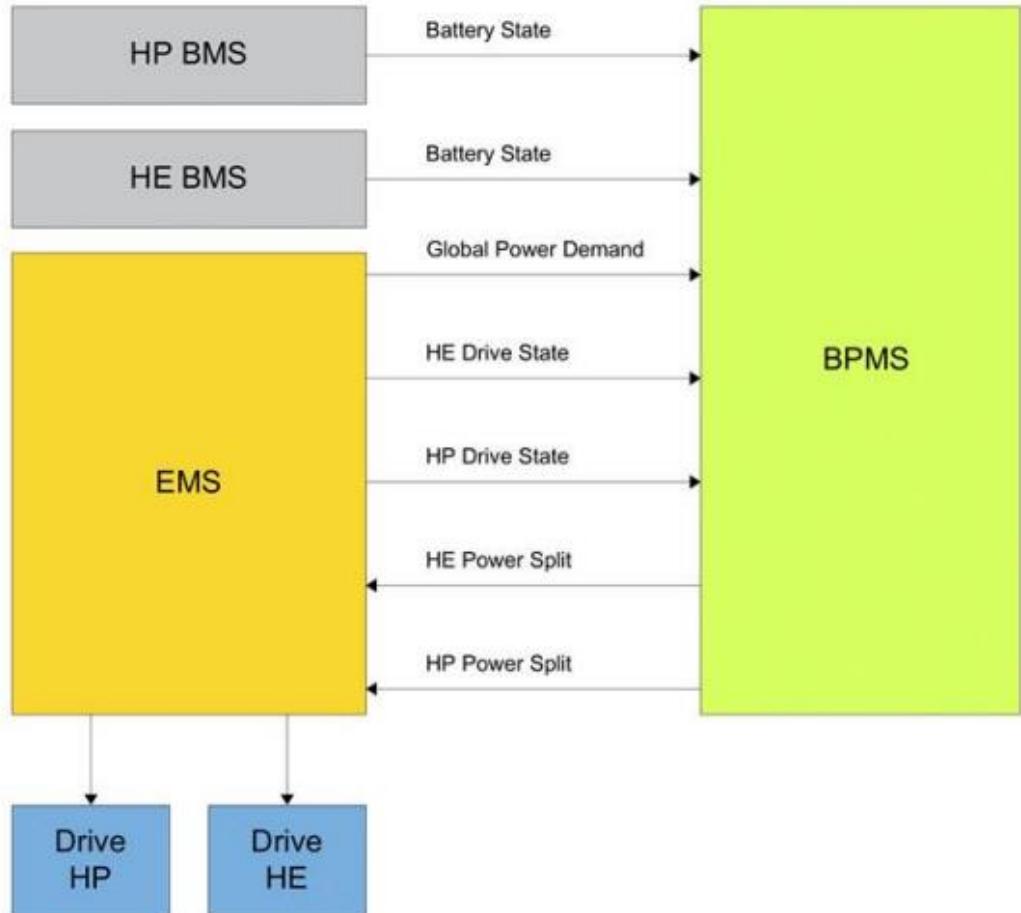


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DATA DEFINITION



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MODBUS COMMUNICATION TABLE



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| Variable name | Access | Type | Address (could be change) | Register length | Unit | description |
|-----------------|-----------------------|---------|---------------------------|-----------------|-------|--|
| BPMS_HB | RW - Holding register | Uint 16 | 40001 | 1 | | BPMS heartbeat signal to check communication status |
| HE_drive_Psplit | RW - Holding register | Int16 | 40002 | 1 | kW/10 | HE drive power split |
| HP_drive_Psplit | RW - Holding register | Int16 | 40003 | 1 | kW/10 | HP drive power split |
| EMS_HB | R - input register | Uint16 | 30001 | 1 | | EMS heartbeat signal to check communication status |
| P_BESS_Demand | R - input register | Int16 | 30002 | 1 | kW/10 | Global power demand = total BESS power (HE and HP) - how much the batteries should deliver |
| VDC_HE_drive | R - input register | Int16 | 30003 | 1 | V/10 | DC voltage of the HE drive |
| IDC_HE_drive | R - input register | Int16 | 30004 | 1 | A/10 | DC Current of the HE drive |
| PDC_HE_drive | R - input register | Int16 | 30005 | 1 | kW/10 | DC side Power of the HE drive |
| PAC_HE_drive | R - input register | Int16 | 30006 | 1 | kW/10 | AC side Power of the HE drive |
| Status_HE_drive | R - input register | Uint 16 | 30007 | 1 | | Status (available, fault, running...) -TBD |
| VDC_HP_drive | R - input register | Float | 30008 | 1 | V/10 | DC voltage of the HE drive |
| IDC_HP_drive | R - input register | Float | 30009 | 1 | A/10 | DC Current of the HE drive |
| PDC_HP_drive | R - input register | Float | 30010 | 1 | kW/10 | DC side Power of the HE drive |
| PAC_HP_drive | R - input register | Float | 30011 | 1 | kW/10 | AC side Power of the HE drive |
| Status_HP_drive | R - input register | Uint 16 | 30012 | 1 | | Status (available, fault, running...) -TBD |



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Results achieved so far:

- BPMS panel production completed
- BPMS FAT completed
- BPMS successfully shipped to Solstad
- BPMS mechanical & electrical installation

Next steps:

- BPMS panel functional tests
- BPMS panel HAT/SAT & commissioning



NEMOSHIP

INNOVATION 1: HETEROGENEOUS BATTERY SYSTEMS AND DEDICATED CONTROL

Battery system installation on Normand Drott vessel

Kjetil Vatland Olsen, Solstad



Normand Drott characteristics

| | |
|------------------------|-----------------------------------|
| Owner Group | Solstad Maritime |
| Built | 2010 |
| Type | Anchor Handling Tug Supply |
| Flag | NOR |
| LOA | 95m |
| Classification Society | DNV GL |
| Dynamic Positioning | DP 2 from Kongsberg |
| Accommodation | 70 Persons |
| Bollard Pull | 339mt |
| Deck Dimensions | 760,2m ² (36,2m x 21m) |
| Deadweight | 5000mt |



PLACEMENT OF BATTERY SYSTEM



NEMOSHIP

- Vard study
- Conversion of fuel oil tank to battery hybrid room



EXECUTION



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- Power consumer skid and battery container lifted onboard into the converted battery hybrid room
- Power consumer lifted onboard and then moved into right position further back.
- Battery container lifted in and moved straight into position.



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CRITICAL ASPECTS INCLUDING DELIVERY TIME FOR EQUIPMENT



NEMOSHIP

- Critical aspects:
 - Safety (e.g., DNV approvals)
 - Cost increases
 - Risks to delay the installation schedule
- Delivery time for equipment:
 - Drives and transformers long delivery time.
 - On order May 2024 to reach installation May 2025



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- Drydocking period and installation time end of April to beginning of July
- Battery functional tests. Alongside prior to sea trials
- Dynamic position (DP) failure model and effects analysis
- DNV battery power notation. Long approval and documentation process





Q&A FOR:

- **Sizing a heterogeneous battery system to fit the vessel needs / Vincent Philippoteau, CEA**
- **Control solution developped for increased BESS lifetime (BPMS) / Clément Retière, CEA**
- **Control solution developped for increased BESS lifetime (BPMS) – Deployment / Mert Can Çelik, Elkon**
- **Battery system installation on Normand Drott vessel / Kjetil Vatland Olsen, Solstad**



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INNOVATION 2: NEMOSHIP DIGITAL PLATFORM FOR OPTIMAL BATTERY OPERATIONS

Overview of the platform capabilities

Roberta Luca, Siemens
Calin Husar, Siemens



NEMOSHIP

CONTENTS

1. Objectives
2. Digital Models
3. Digital Platform
4. Deployment & Preliminary Feedback



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NEMOSHIP PROJECT OBJECTIVES

OBJECTIVES OF THE PROJECT



NEMOSHIP

1. Flexible electrification solutions to exploit heterogeneous storage units for a wide range of needs

- Limit the number of system components
- Widen the grid services provided by large battery systems
- Decrease CAPEX thanks to hybridisation
- Improve battery lifetime

2. Standardisation of the battery systems integration process and interfaces within the vessels

- Decrease BESS installation costs around 40%
- Contribute in LTI (Lost Time Incident / Injuries) reduction
- Increase maintenance capability of the crew members

3. Advanced tools for ship operators and owners to reach an optimal and safe exploitation

- Interface with existing third-party software used
- Improve global efficiency of ESS exploitation of above 10%
- Decrease maintenance occurrences
- Increase number of crew members trained

Experiences from ESS exploitations

4. Extending zero emission ability for both hybrid and full-electric ships

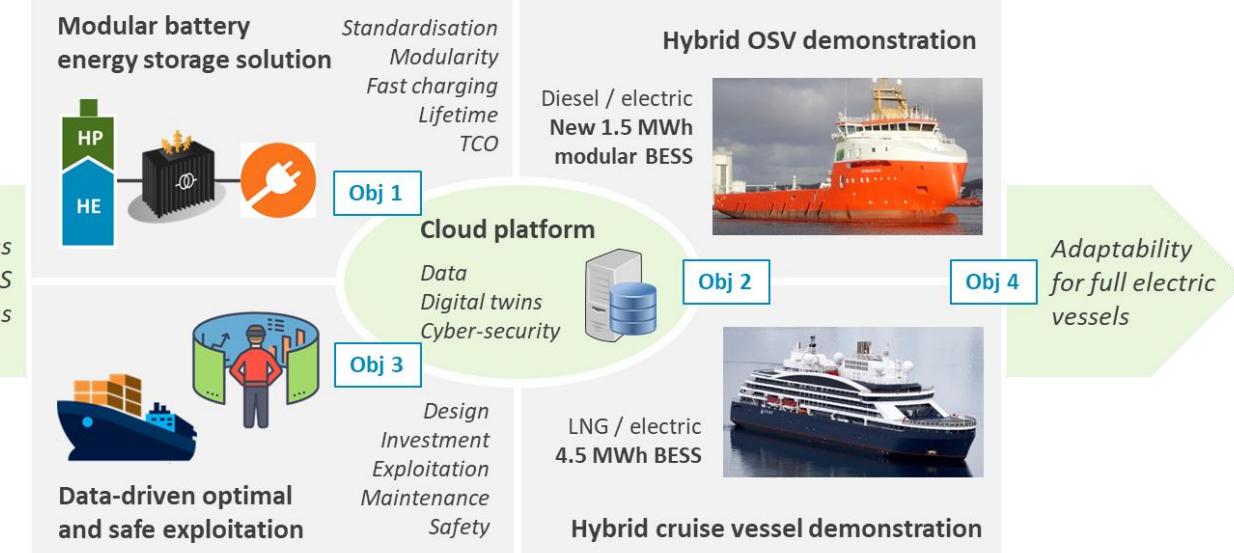
- Increase zero-emission transit
- Decrease CII (Carbon Intensity Index) for each vessel
- Improve full-electric arrangement sailing distance

➤ **Outcome 1:** Development and validation of a 1.5 MWh modular BESS and its BPMS for a retrofitted hybrid vessel

➤ **Outcome 2:** Provide integration methodologies and standards thanks to a Formal Safety Assessment

➤ **Outcome 3:** Development and validation of a cloud-based digital platform enabling a data-driven exploitation

➤ **Outcome 4:** Two real hybrid demonstration vessels reaching above TRL7 and two virtual full-electric demonstrations reaching TRL6 in laboratory





Trains crew members to evaluate how different onboard configurations during past trips may have affected key performance indicators (KPIs), such as fuel consumption, power, and emissions. All results are archived for easy access and future reference.



Offers guidance to the crew on the operation of generators and the battery system for a future trip in order to minimize costs, emissions, or both of them.



Provides visualization and export capabilities for the simulation results.



Allows the user to analyze the impact of using the batteries for past trips or a custom time period from the past.



Facilitates access to a Battery Diagnostic Tool.



NEMOSHIP

DIGITAL MODELS

Simcenter Amesim



Le Commandant Charcot



*Icebreaking
cruise ship*

Normand Drott



*Offshore
supply ship*

Full Electric Vessel



*Virtual
use case*

Fuel Cell Vessel



*Virtual
use case*

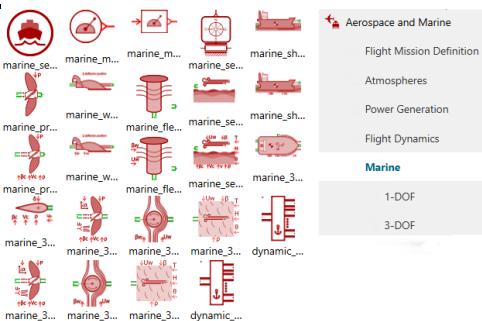
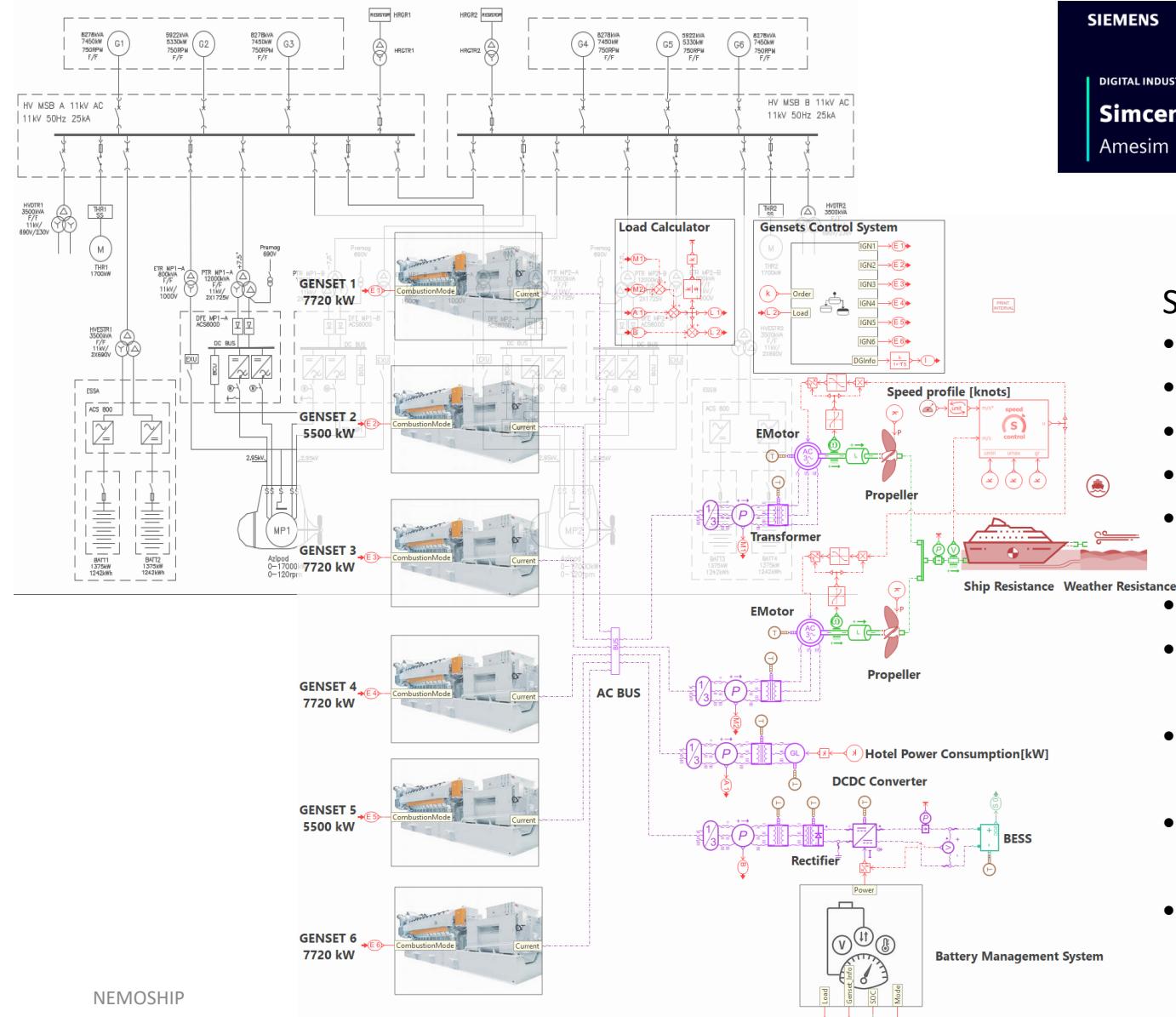
Digital Twin

A **1D simulation** for a specific use case, developed using a **virtual platform** and fed with *real data*

STANDARD DIGITAL TWIN FOR PONANT USE CASE



NEMOSHIP



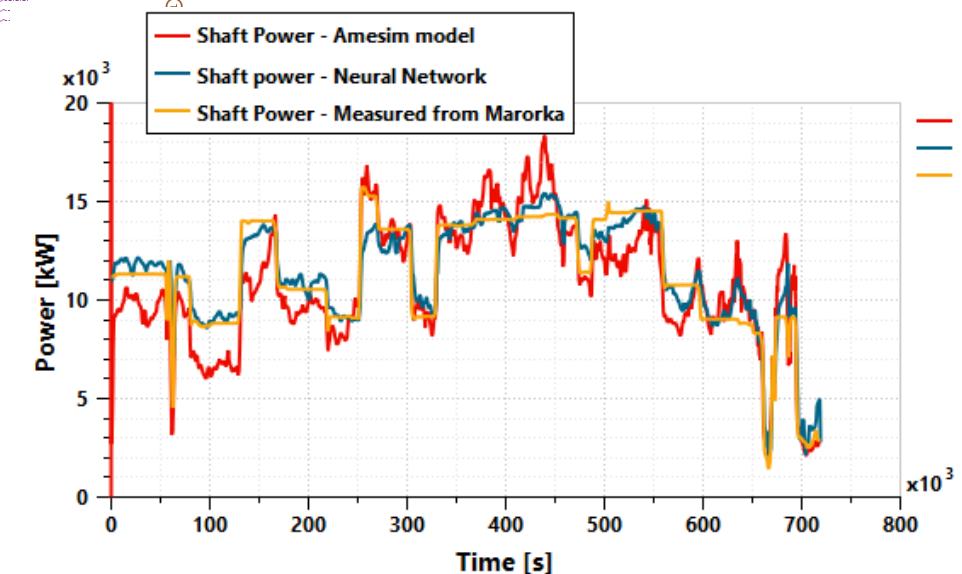
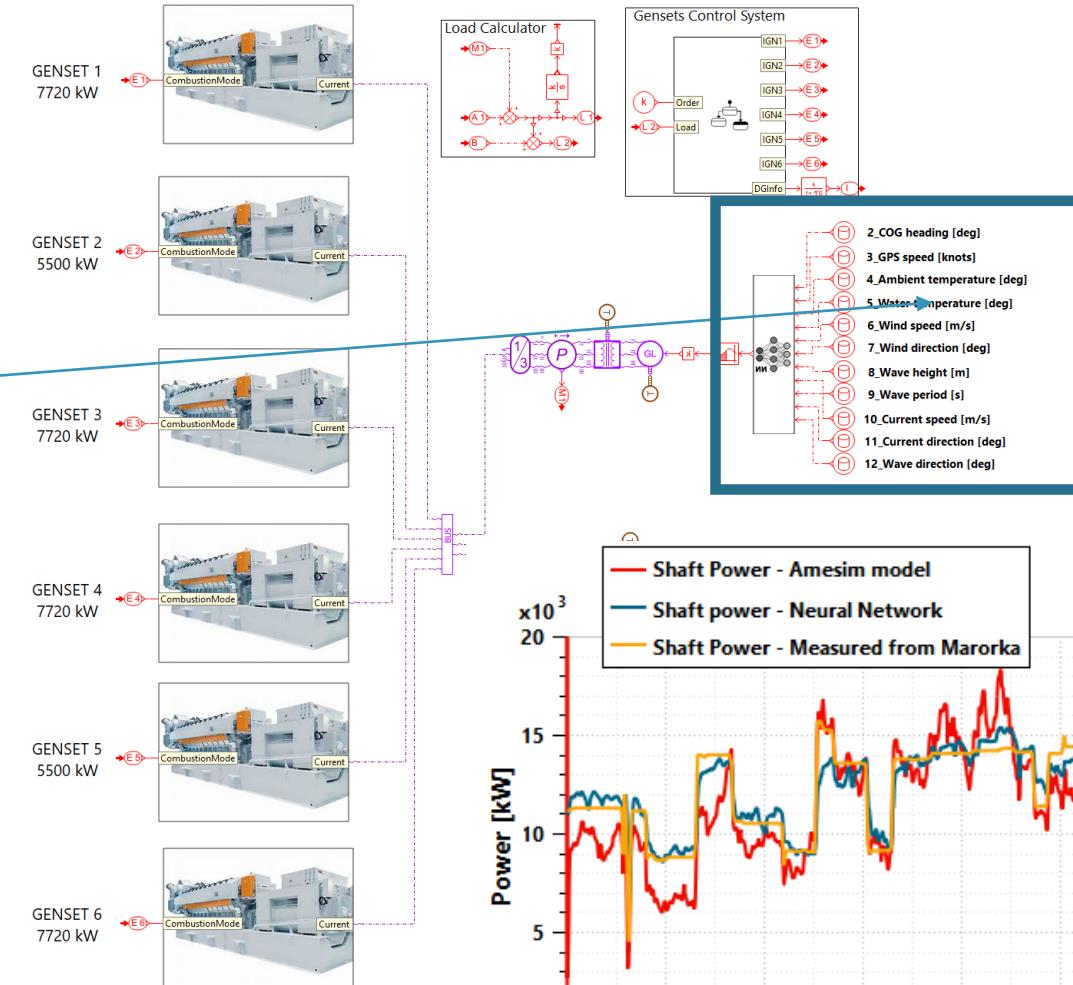
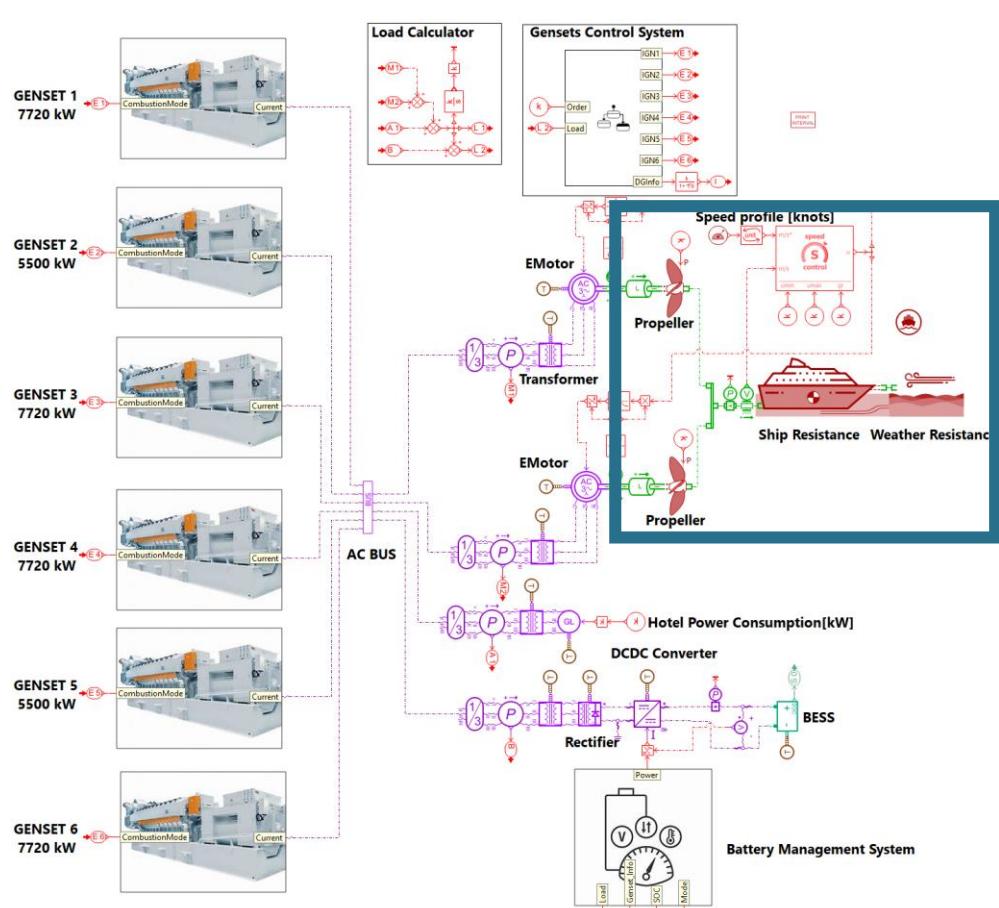
Standard Digital Twin for Ponant use case contains:

- Ship resistance model + Weather resistance component
- 2 propellers
- 2 electric motors
- 4 transformers, one rectifier and one DC/DC converter
- Speed control components – converts the speed profile into torque command for electric motors
- BESS - 4520 kWh Corvus Orca equivalent
- BMS with 4 battery modes: Peak Shaving, Charging, Discharging, ZEO.
- 6 gensets – 2 x Wartsila 31DF V10 5500 kW – 4 x Wartsila 31DF V14 7720 kW
- Genset control system – ensures automatic starting and stopping of the gensets
- Load calculator – used to calculate power demand

HYBRID MODEL IMPLEMENTATION



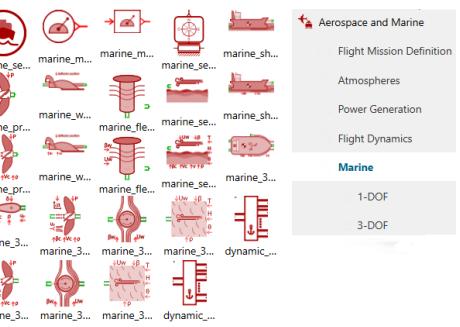
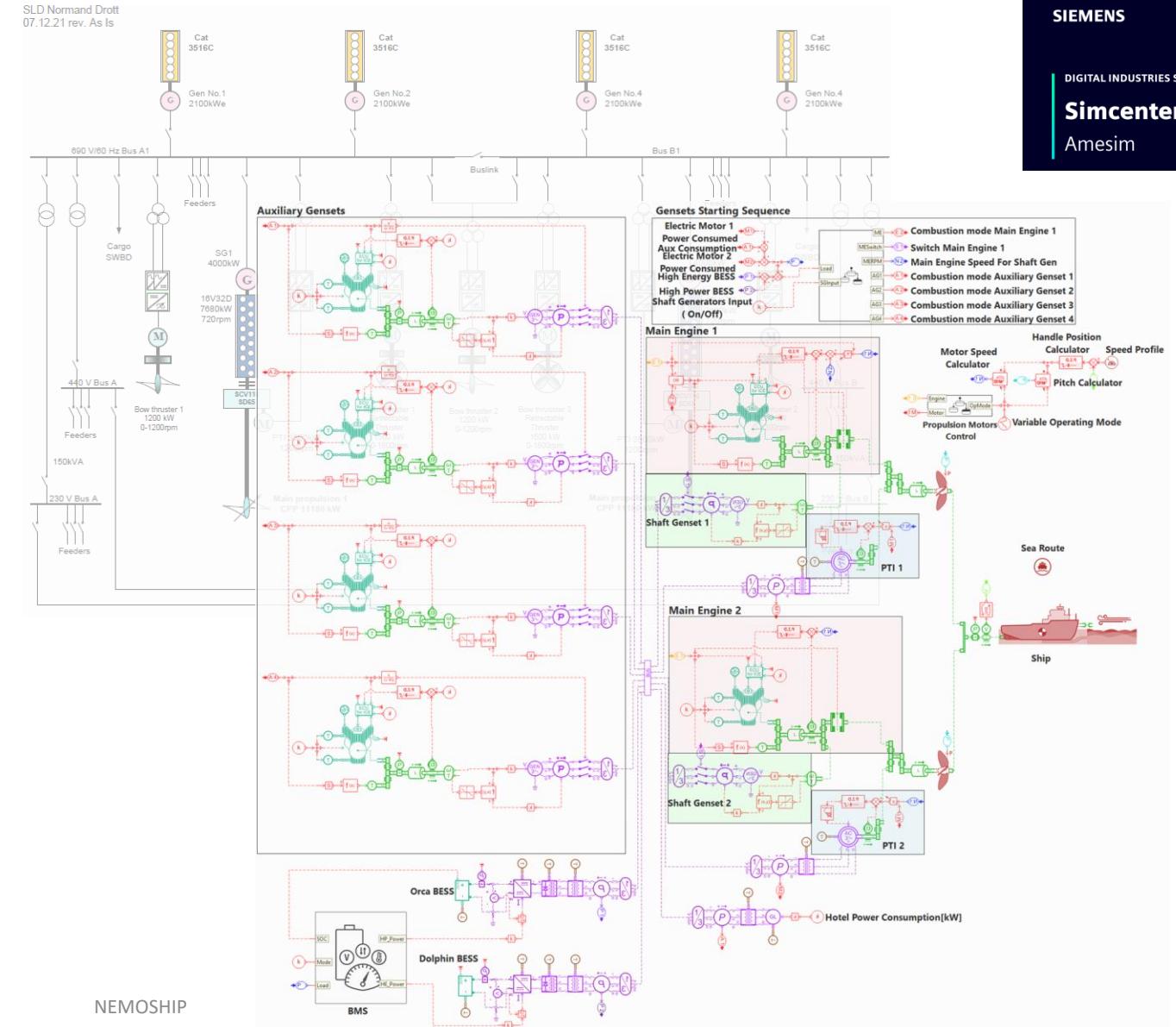
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STANDARD DIGITAL TWIN FOR SOLSTAD USE CASE



NEMOSHIP

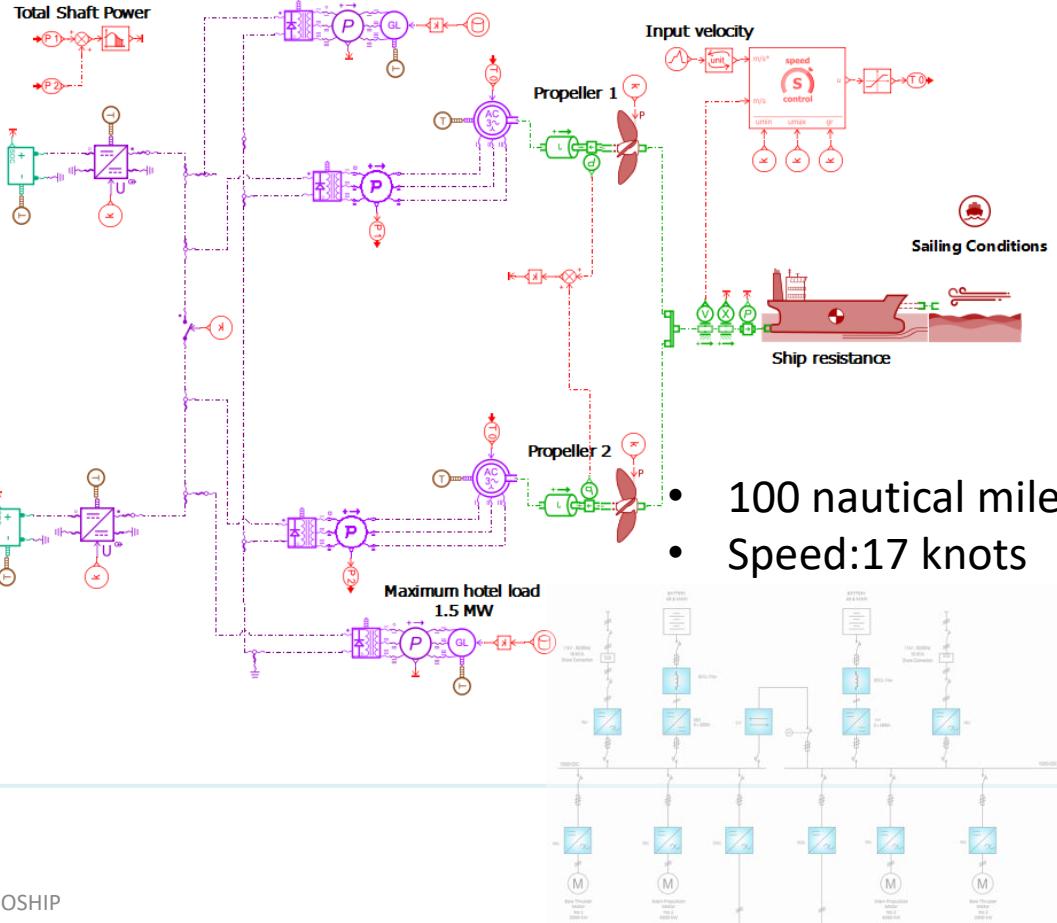


Standard Digital Twin for Solstad use case contains:

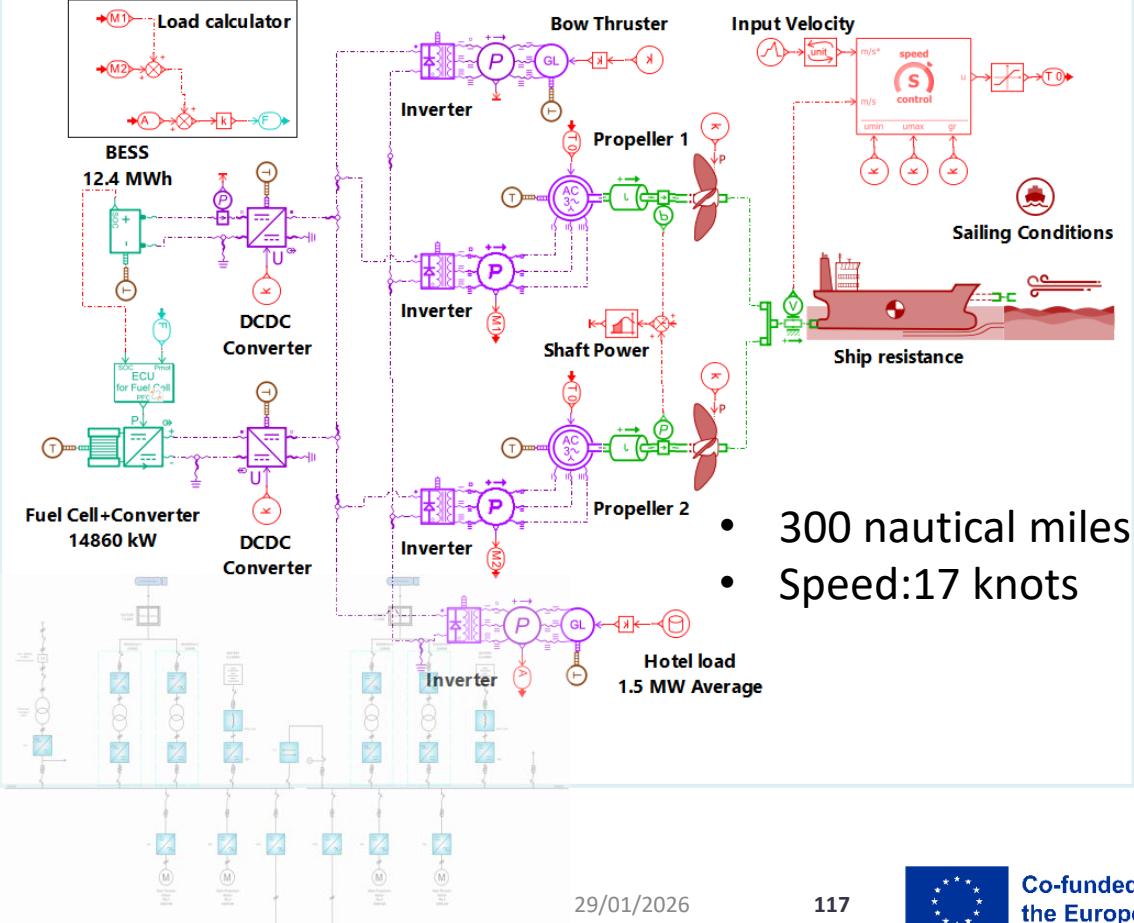
- Ship resistance model + Weather resistance component
- 2 propellers
- 2 Main Engines with shaft generators + 2 PTIs
- 4 transformers, 2 rectifier and 2 DC/DC converter
- PTI speed and pitch calculator
- BESS - HP - 746 kWh Corvus Orca equivalent
 - HE - 361 kWh Dolphin Energy NxtGen equivalent
- BMS with one battery mode: Peak Shaving
- 4 Auxiliary gensets – Caterpillar 3516c
- Genset control system – ensures automatic starting and stopping of the gensets
- Load calculator – used to calculate power demand



Full Electric Vessel



Fuel Cell Vessel





NEMOSHIP

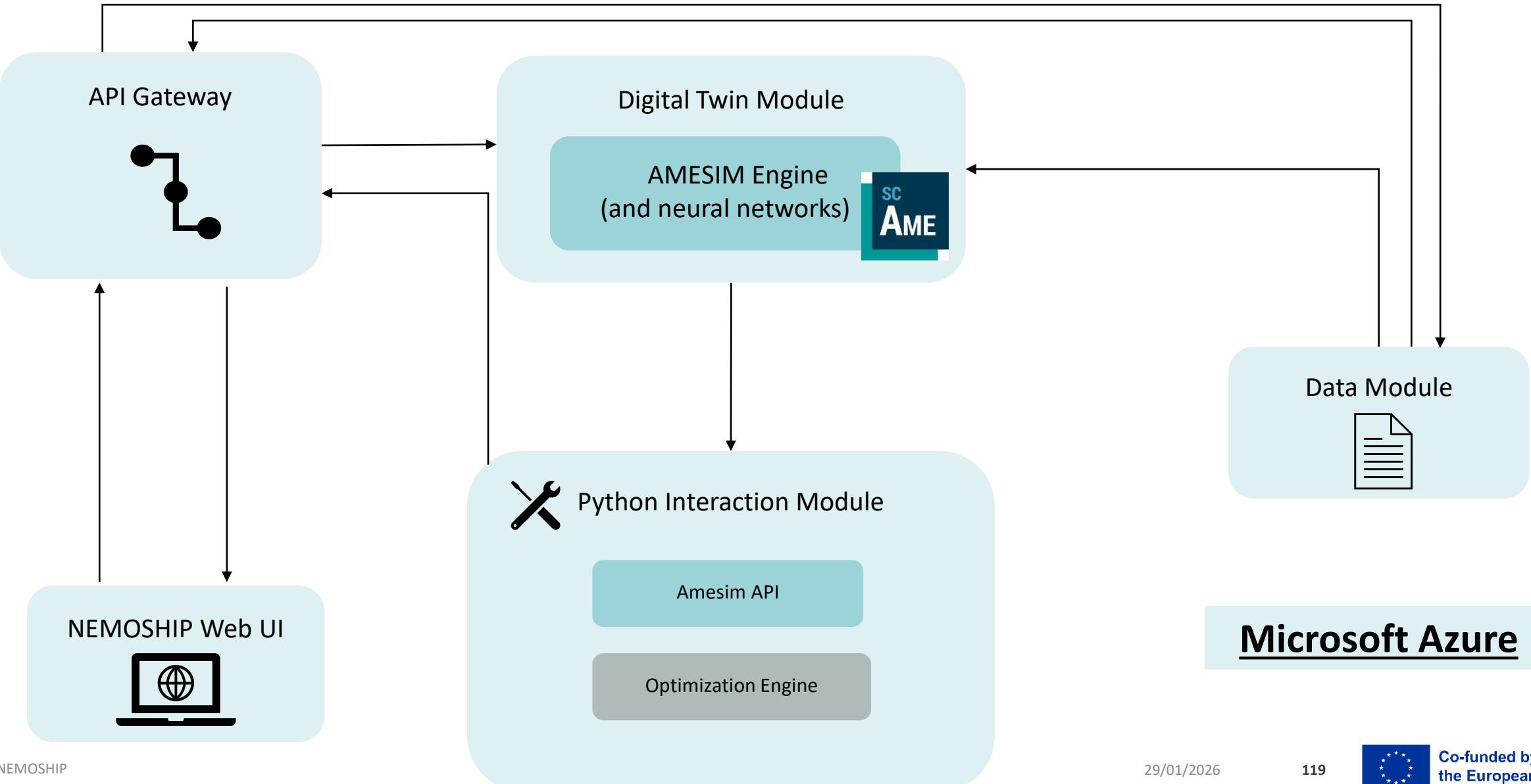
NEMOSHIP DIGITAL CLOUD PLATFORM

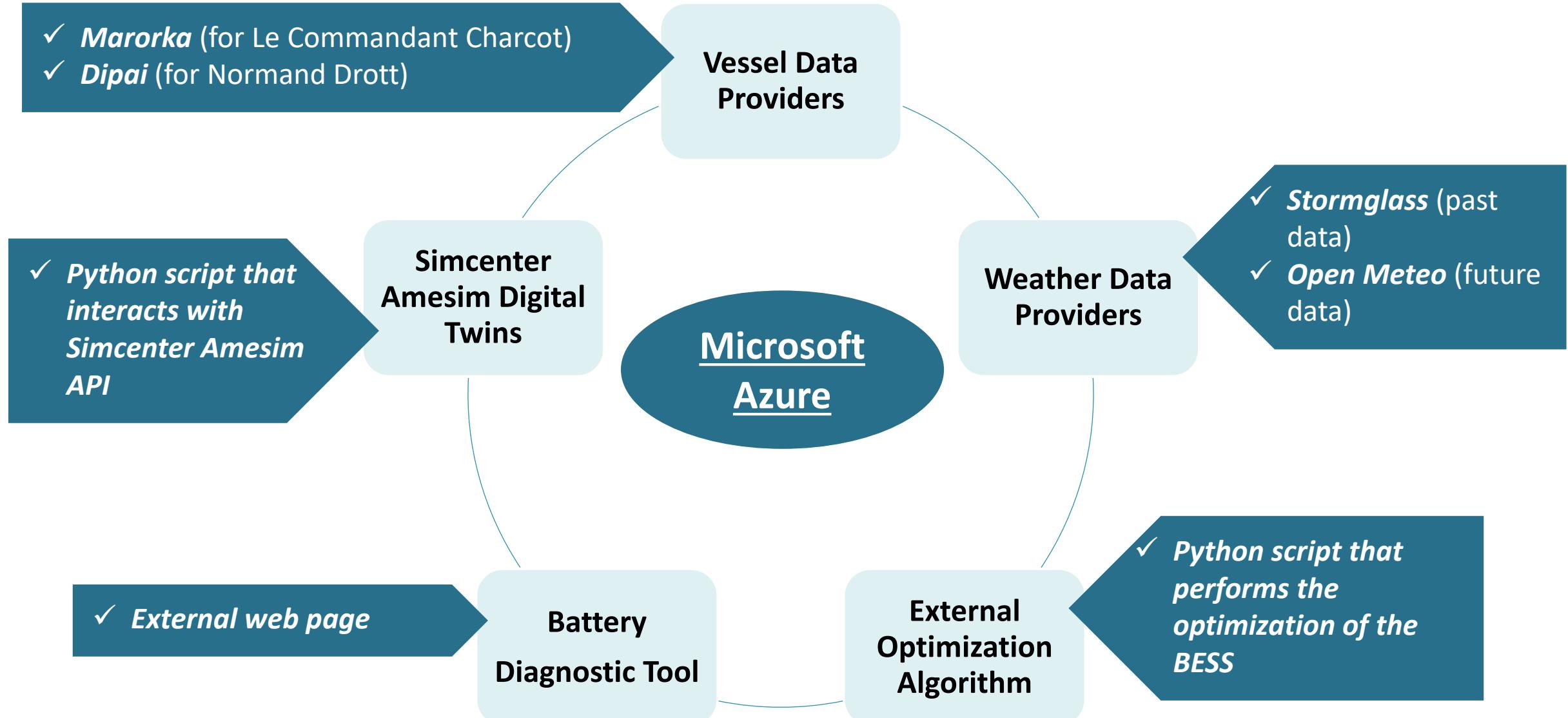
nemoship.azurewebsites.net

MODULAR CYBERSECURED ARCHITECTURE



NEMOSHIP





FUNCTIONALITY



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Use Case

✓ *Le Commandant Charcot*

- ✓ Developed to assess **the impact of battery usage** over a defined period, focusing on various operational modes:

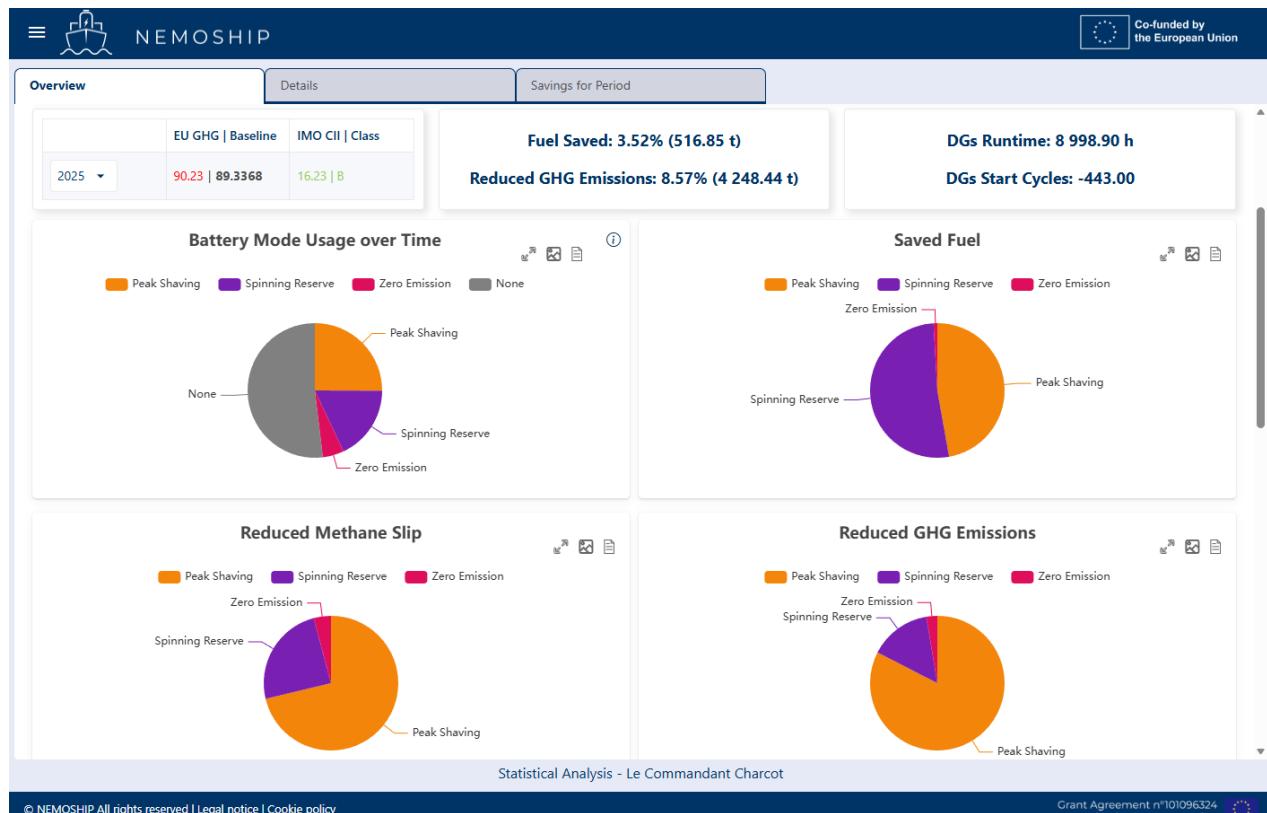
- *Zero Emissions*
- *Peak Shaving*
- *Spinning Reserve*

Objective

- ✓ Overview details for the full analyzed period
- ✓ Details per trip
- ✓ Details for a custom period

KPIs

- ✓ *Fuel Consumption*
- ✓ *GHG Emissions*
- ✓ *Methane CO2eq Emissions*





Use Cases

- ✓ *Le Commandant Charcot*
- ✓ *Normand Drott*

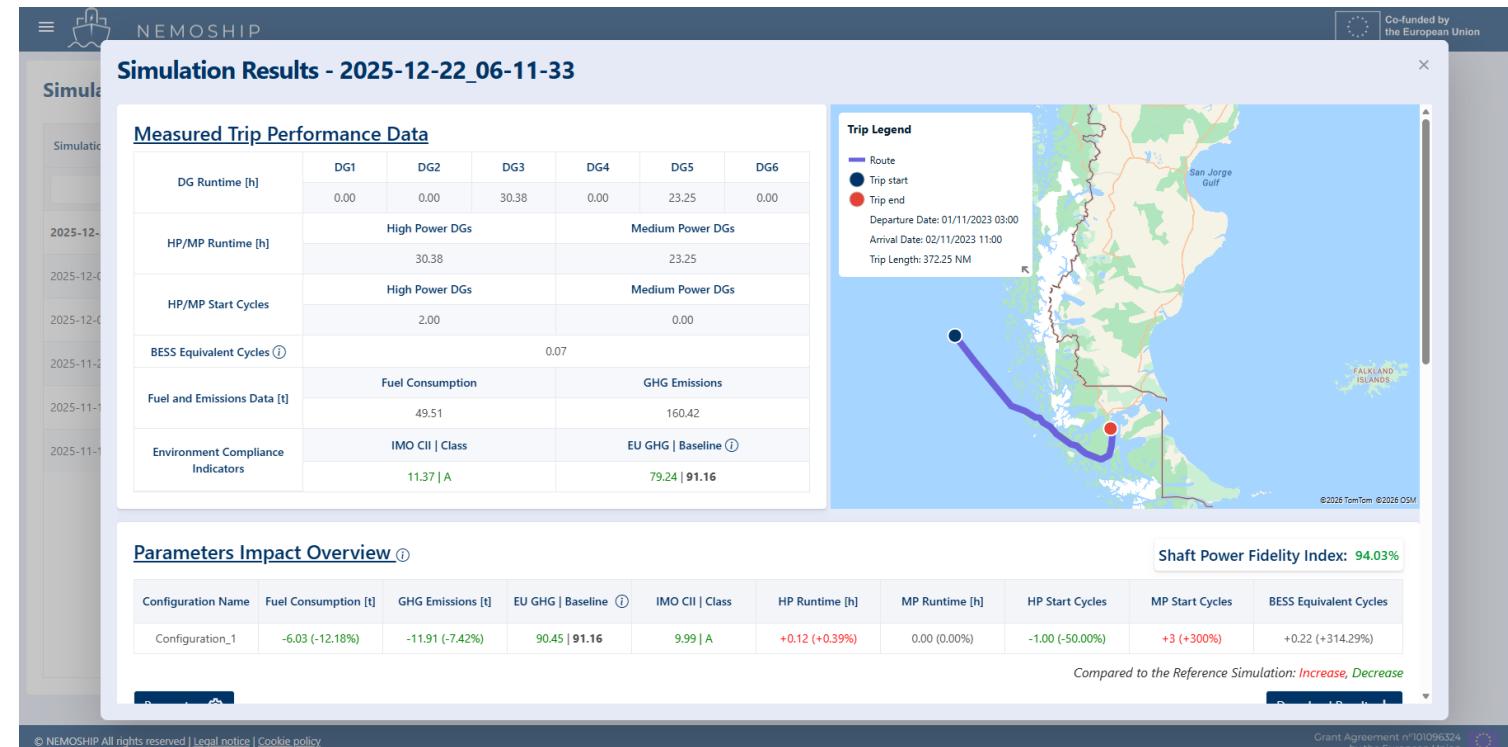
- ✓ Allows the user to select a past trip and **modify various parameters** to analyze their impact on key performance indicators

Objective

- ✓ The core objective is to explore “what-if” scenarios for performance and efficiency evaluation

Amesim

- ✓ At the heart of this module is a **Simcenter Amesim digital model**, ensuring robust and realistic system behavior modeling
- ✓ The digital model was validated against real-world data provided by the vessel data system (Marorka and Dipai, for each vessel)





Use Cases

- ✓ *Le Commandant Charcot*
- ✓ *Normand Drott*

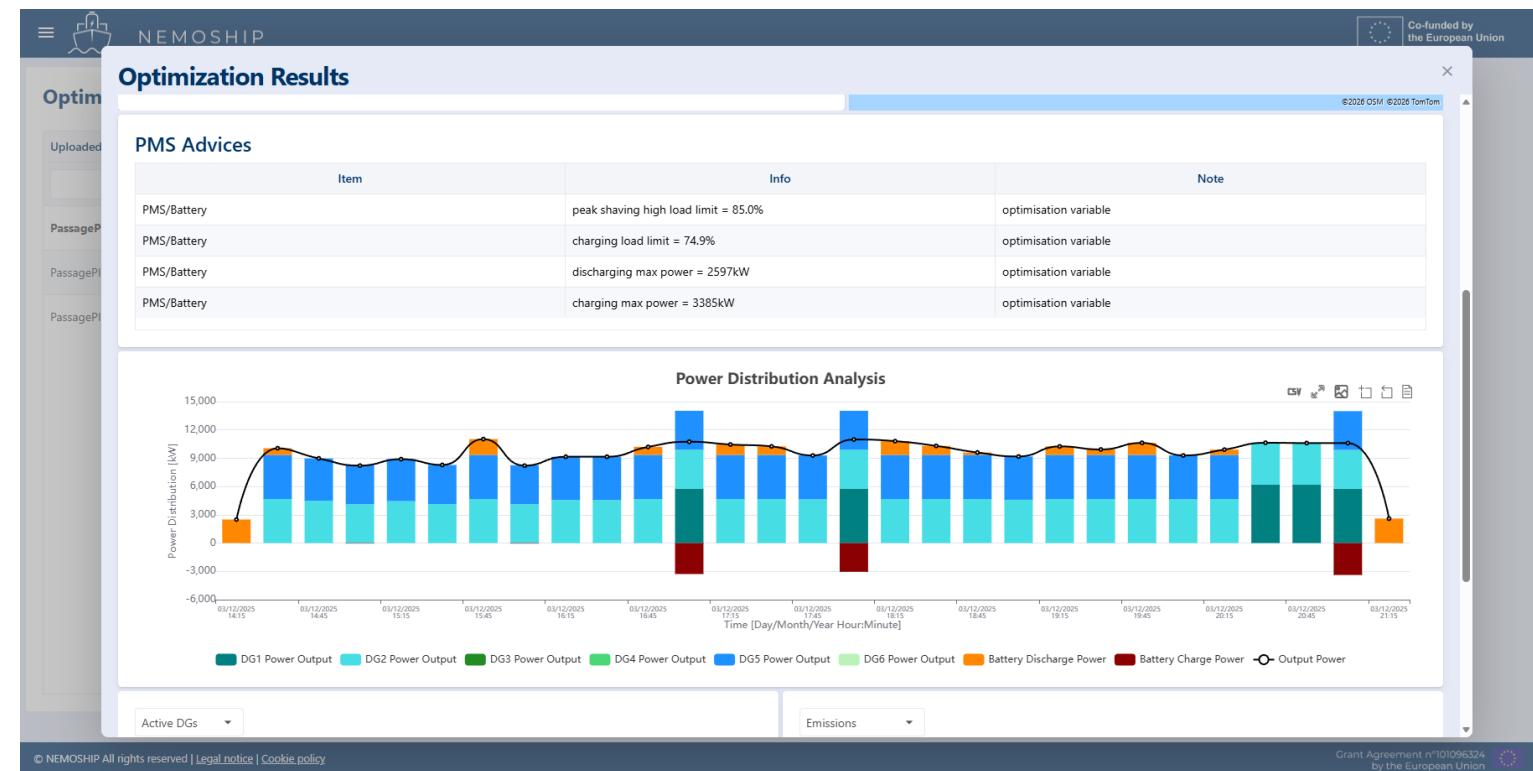
- ✓ Designed to support the crew in **optimizing the Battery Energy Storage System** for upcoming trips, aiming to reduce costs and emissions

Objective

- ✓ The **power profile** for the imported route is generated by the **digital model** developed in **Simcenter Amesim** based on the route, weather conditions, and different activities defined by the crew

Optimization

- ✓ The optimization algorithm uses the power profile and the user-defined parameters as inputs to **minimize costs** and **emissions**



INTERACTION WITH THE BATTERY DIAGNOSTIC TOOL



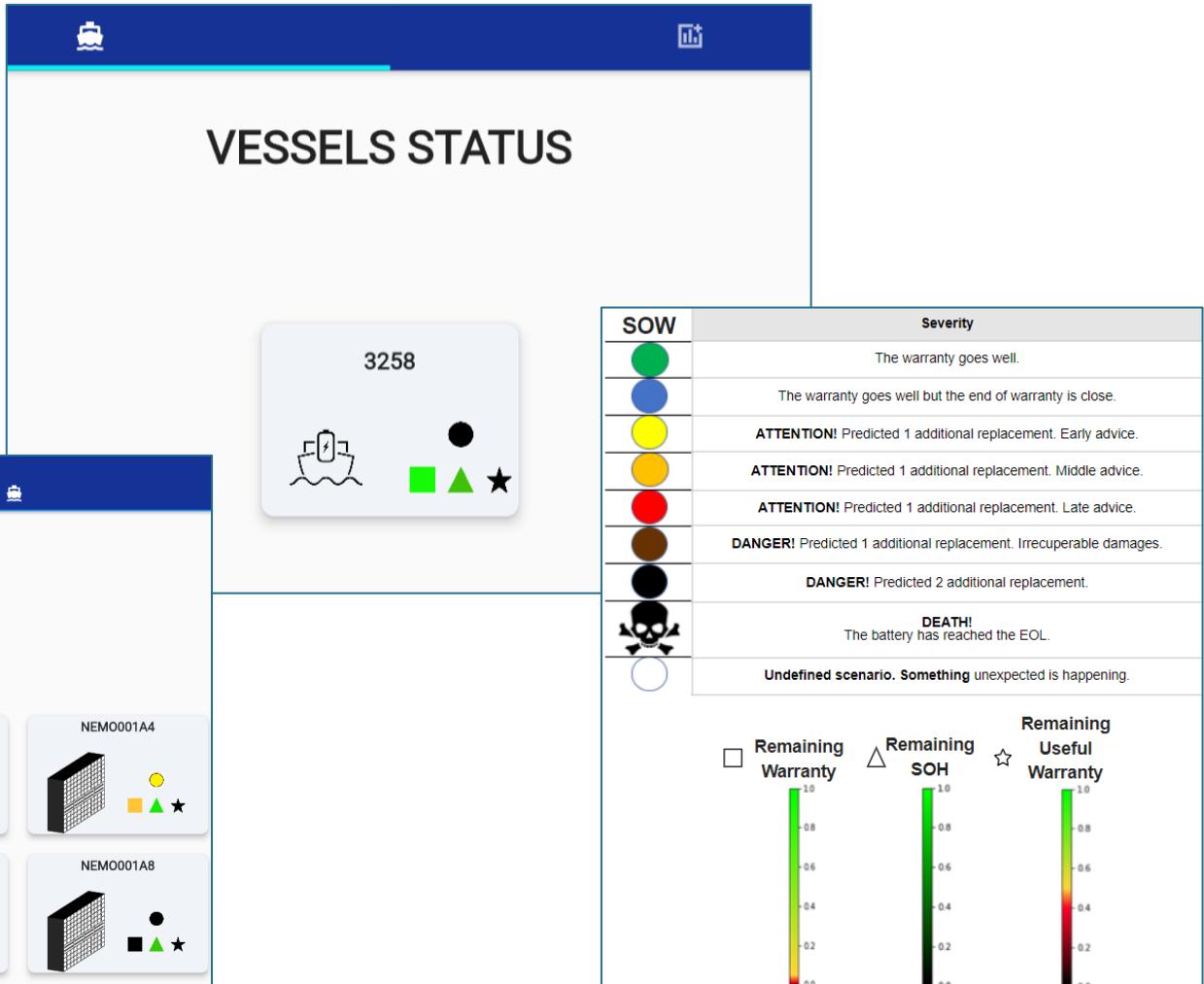
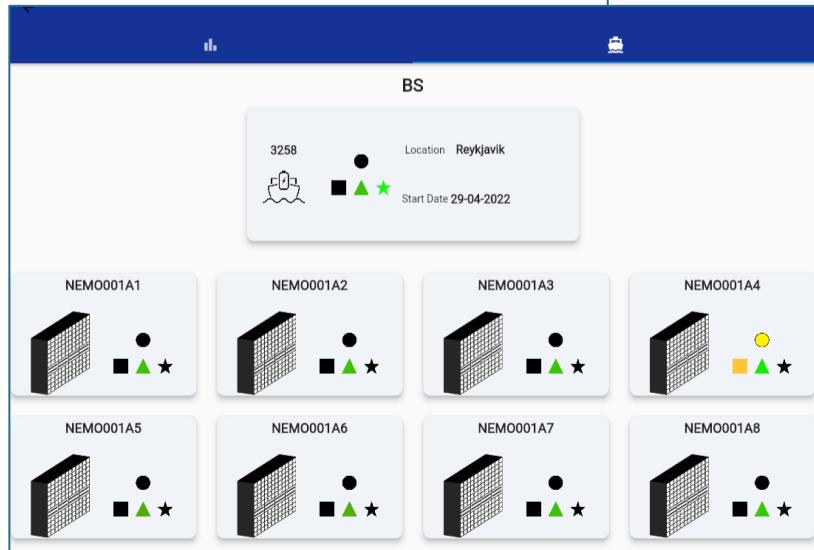
NEMOSHIP

Use Cases

- ✓ *Le Commandant Charcot*
- ✓ *Normand Drott*

- ✓ Defines predictive maintenance and diagnostic indicators based on the collected data and expected use of batteries

Objective





Use Cases

- ✓ *Le Commandant Charcot*
- ✓ *Normand Drott*

- ✓ Provide allocated storage space for documents that users wish to retain for future analysis or share with partners, with the option to restrict access as needed

Objective

OneDrive

+ New ▾ Upload ▾ Share Add shortcut to My files

Sort ▾ Details

Nemoship Data Sharing

| Name | Modified | File size | Sharing |
|---|-----------|-----------|---------|
| NEMOSHIP_Digital_Platform_v1.pptx | 5/15/2025 | 21.5 MB | Shared |
| NEMOSHIP_Digital_Platform_v1_short.pptx | 5/15/2025 | 5.77 MB | Shared |

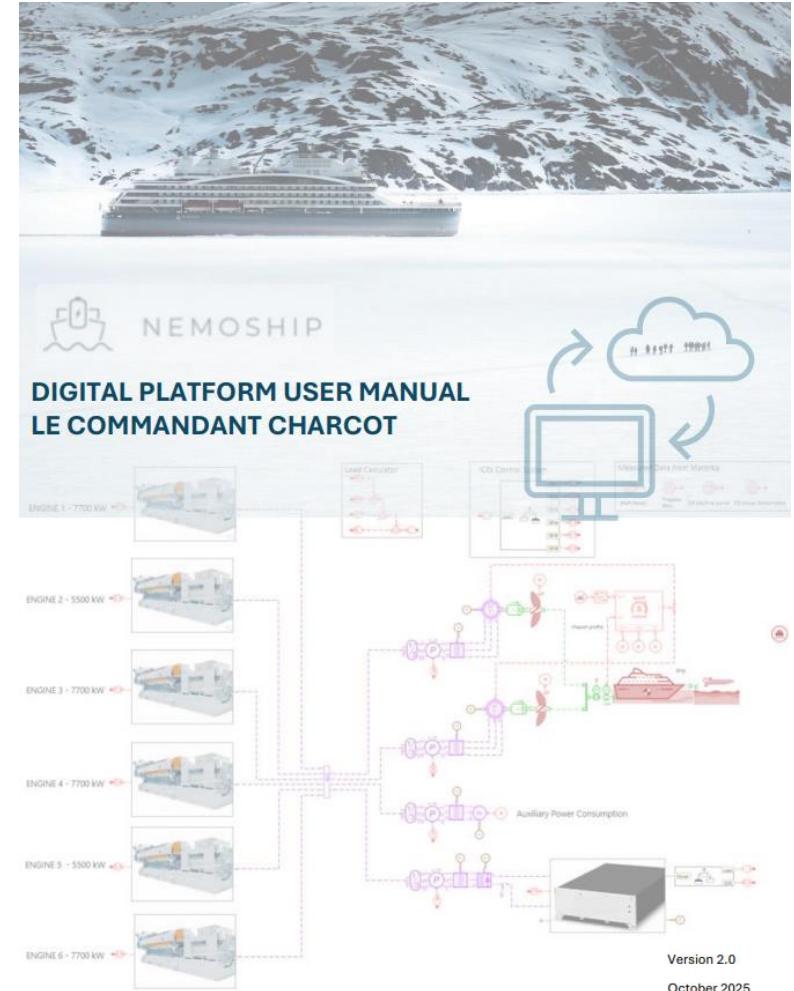


Use Cases

- ✓ *Le Commandant Charcot*
- ✓ *Normand Drott*

Objective

- ✓ Provides comprehensive instructions for the use of the NEMOSHIP Digital Platform



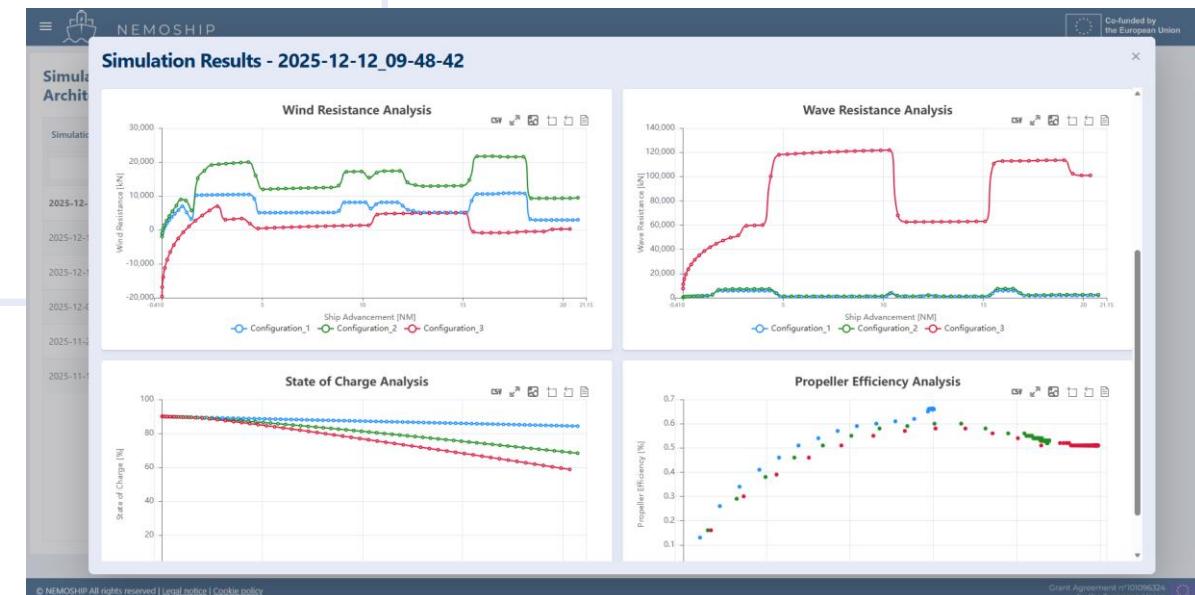
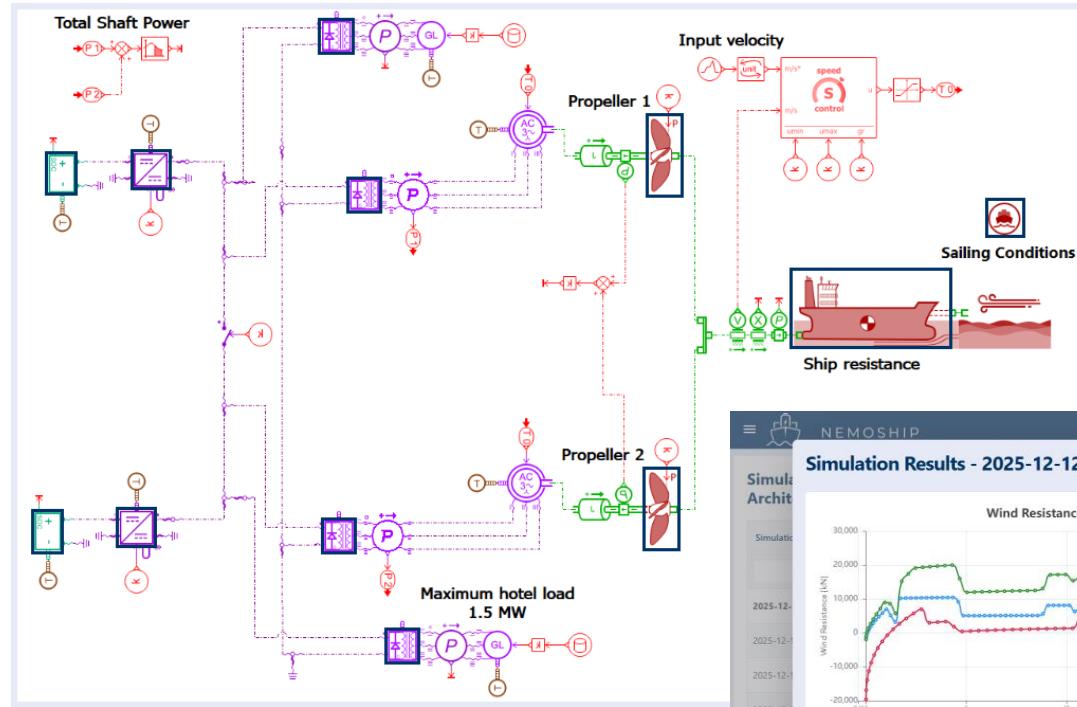


Use Cases

- ✓ Full Electric
- ✓ Fuel Cell

Objective

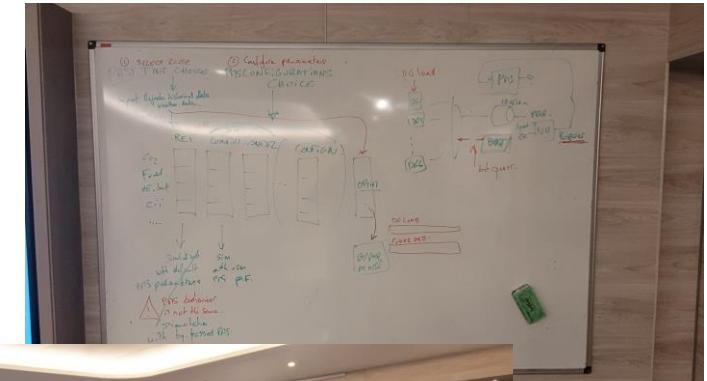
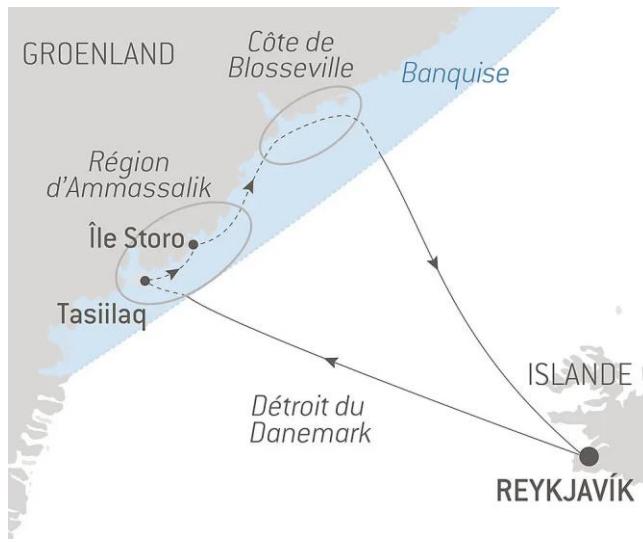
- ✓ Allows the user to select a predefined trip and **modify various parameters** to analyze their impact on different key performance indicators



DEPLOYMENT ON LE COMMANDANT CHARCOT: 14-24 MAY 2025



NEMOSHIP



Purpose of the visit: gain practical insights into vessel operations, decision-making processes, and the energy management strategy

Key Activities

- Observed daily vessel operations
- Analyzed captain – chief engineer communication and decisions
- Reviewed Power Management System (PMS) setup and control
- Organized meetings with project partners and crew:
 - Captain
 - Chief engineer
 - Planning officer





NEMOSHIP

INNOVATION 2: NEMOSHIP DIGITAL PLATFORM FOR OPTIMAL BATTERY OPERATIONS

Preliminary feedback following deployment on Le
Commandant Charcot vessel

Mathieu Petiteau, Ponant

HISTORICAL DATA ANALYSIS MODULE TEST



NEMOSHIP

→ Comparison between real vessel data versus NEMOSHIP DP simulated vessel fuel consumption and emissions without BESS

Data collected from Sept 2022 to November 2025

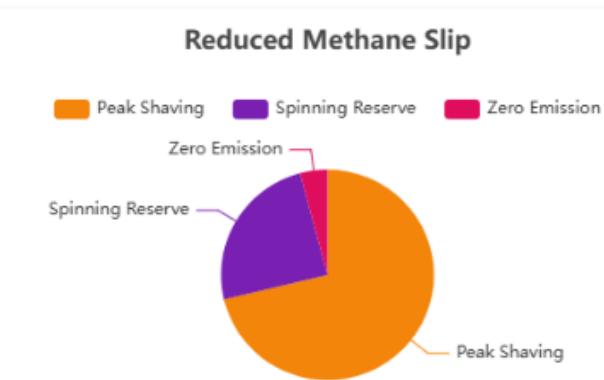
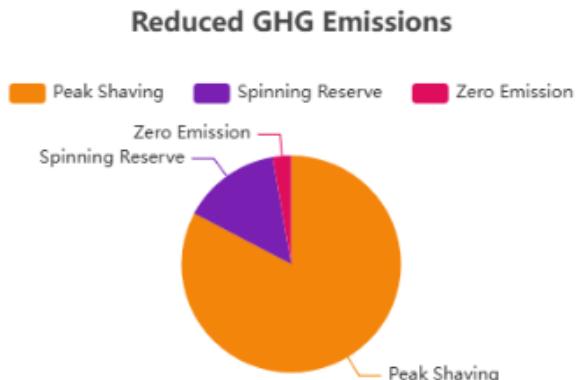
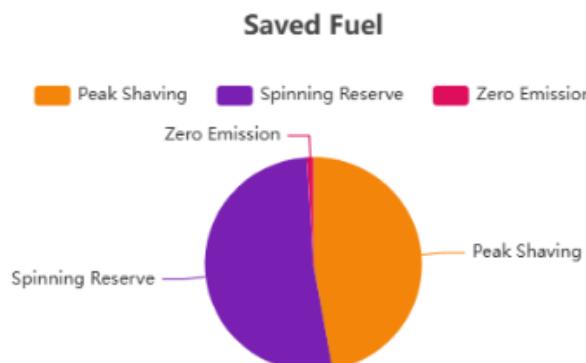


Fuel Saved: 3.52% (516.85 t) *
Reduced GHG Emissions: 8.57% (4248.44 t)

* Savings calculated during period of time battery active modes have been detected by DP

| GLOBAL | % of fuel saved | tons of fuel | Spinning Reserve | Peak Shaving | Zero Emission |
|---------------|-----------------|--------------|------------------|--------------|---------------|
| fuel saved | 3,50% | 517 | 52% | 47% | 1% |
| GHG reduction | 8,80% | 4248 | 14% | 83% | 3% |

→ Peak shaving mode is contributing the most to the GHG saving
Peak shaving and spinning reserve modes are contributing equally to fuel savings



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HISTORICAL DATA ANALYSIS MODULE TEST



NEMOSHIP

BATTERY USE MODE ANALYSIS

| | GENERAL | 2025 | 2024 | 2023 |
|-----------------------|------------|------------|------------|------------|
| ZE | 6% | 4% | 8% | 1% |
| PS | 27% | 21% | 22% | 17% |
| SR | 14% | 13% | 12% | 10% |
| NONE | 53% | 63% | 58% | 71% |
| Fuel Saved t | 517 | 161 | 158 | 116 |
| Fuel Saved € (800€/t) | 413 600 | 128 800 | 126 400 | 92 800 |
| Fuel Saved % | 3,50% | 4,25% | 3,23% | 2,70% |
| GHG % | 9% | 11% | 10% | 7% |
| Methane % | 32% | 31% | 33% | 35% |
| Heure DG saved | 7800 | 2580 | 2800 | 2300 |

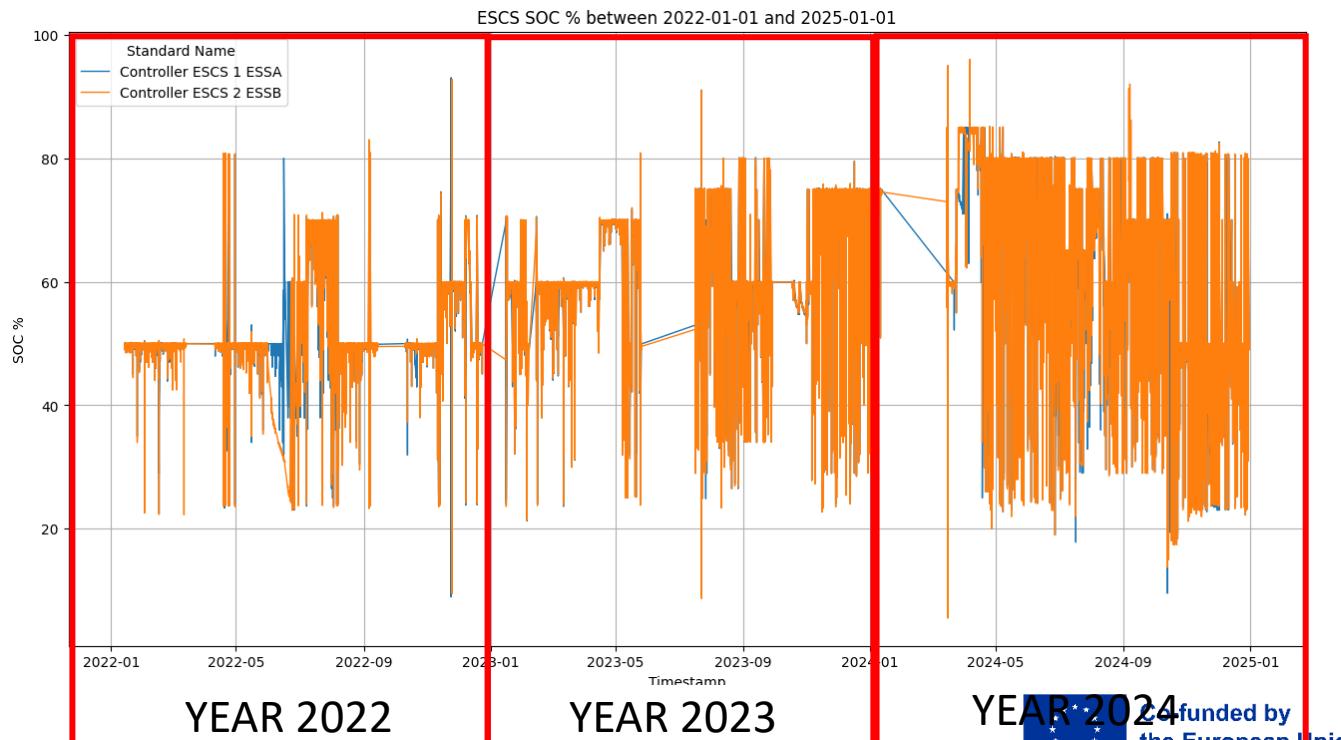
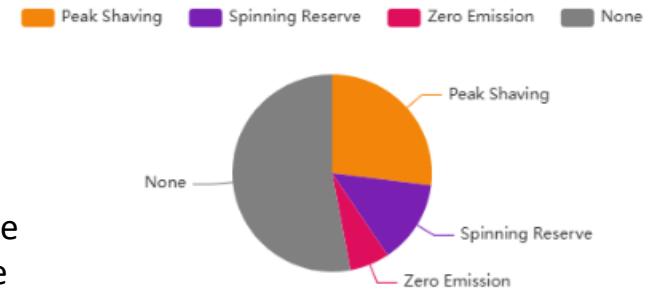
→ CONSERVATIVE RESULTS / SAVINGS

Upgrades to come

Very few contribution of the ZE mode to fuel saving

Too much time outside of any battery mode. Not according to the timeseries of battery energy profile

Battery Mode Usage over Time





BATTERY USE MODE ANALYSIS

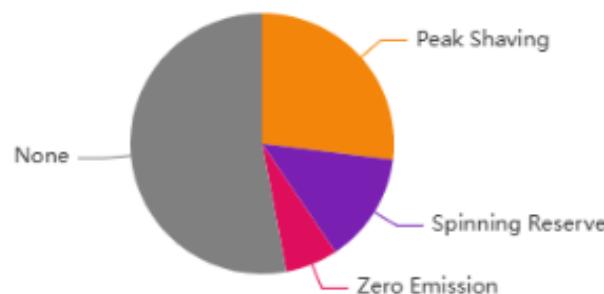
| | GENERAL | 2025 | 2024 | 2023 |
|------------------------|---------|---------|---------|--------|
| ZE | 6% | 4% | 8% | 1% |
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| GHG % | 9% | 11% | 10% | 7% |
| Methane % | 32% | 31% | 33% | 35% |
| Running hours DG saved | 7800 | 2580 | 2800 | 2300 |

Peak Shaving is the most used mode

BESS contribution on Methane slip savings is >30%
BESS provides high GHG benefits for LNG Dual fuel vessel

Battery Mode Usage over Time

Peak Shaving Spinning Reserve Zero Emission None



Within 3 years, 7800 running hours of Diesel Engine have been saved



Q&A FOR:

- **Overview of the platform capabilities / Roberta Luca and Calin Husar, Siemens**
- **Preliminary feedback following deployment on Le Commandant Charcot vessel / Mathieu Petiteau, Ponant**



NEMOSHIP

APPLICABILITY TO FULL ELECTRIC USE CASES

Thibaut Tincelin, SDI

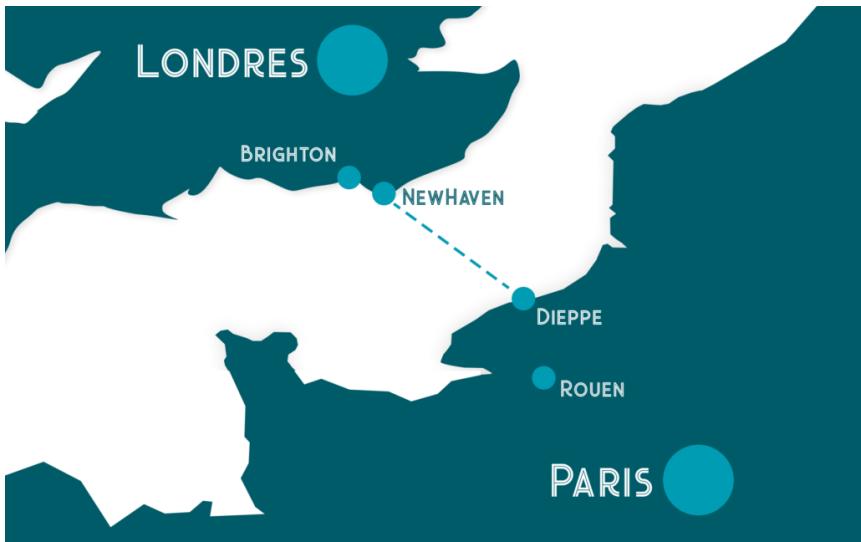
APPLICABILITY FOR FULL-ELECTRIC SHIP : REFERENCE SHIP



NEMOSHIP

Reference Ship: DFDS COTE D'ALBATRE

- Typical speed: **17 knots** about
- Sea passage: **66 Nm** (Dieppe – Newhaven)



Principal particulars

| | | |
|--|--------|-----|
| Length overall | 142,63 | m |
| Length between perpendiculars | 125,00 | m |
| Breadth, moulded | 24,20 | m |
| Depth, moulded | 8,35 | m |
| Summer load line draught, moulded | 5,70 | m |
| Deadweight at summer load line draught | 2 649 | DWT |
| Gross tonnage | 18 951 | GT |

APPLICABILITY FOR FULL-ELECTRIC SHIP : REFERENCE SHIP



NEMOSHIP



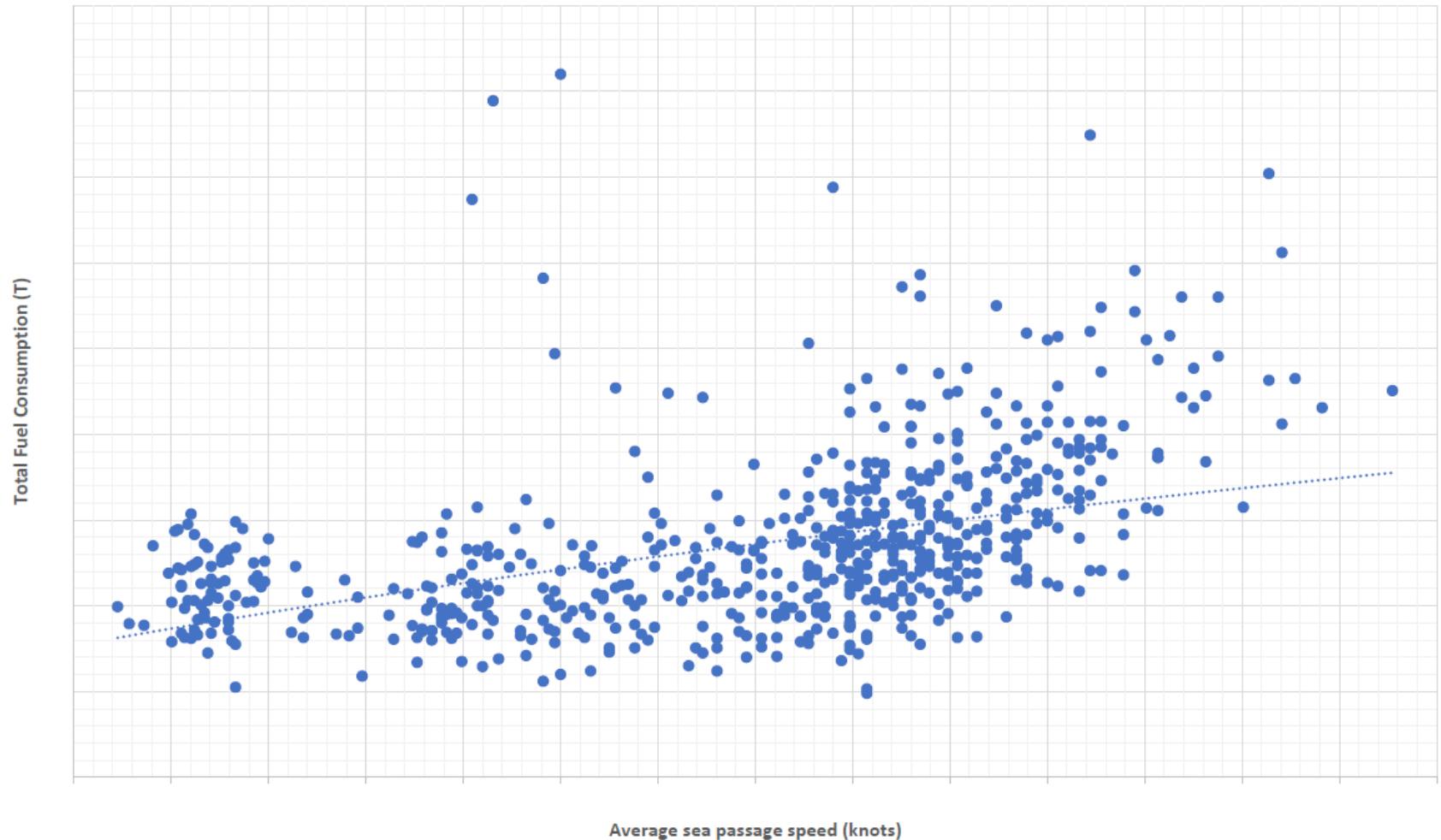
NEMOSHIP - WP7 - Total Energy consumption variation per trip compared to average sea passage speed per trip - Source : DFDS

Reference ship:

DFDS COTE D'ALBATRE



Speed / Power data



Average sea passage speed (knots)



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APPLICABILITY FOR FULL-ELECTRIC SHIP: REFERENCE SHIP



NEMOSHIP

SDI

Reference ship:

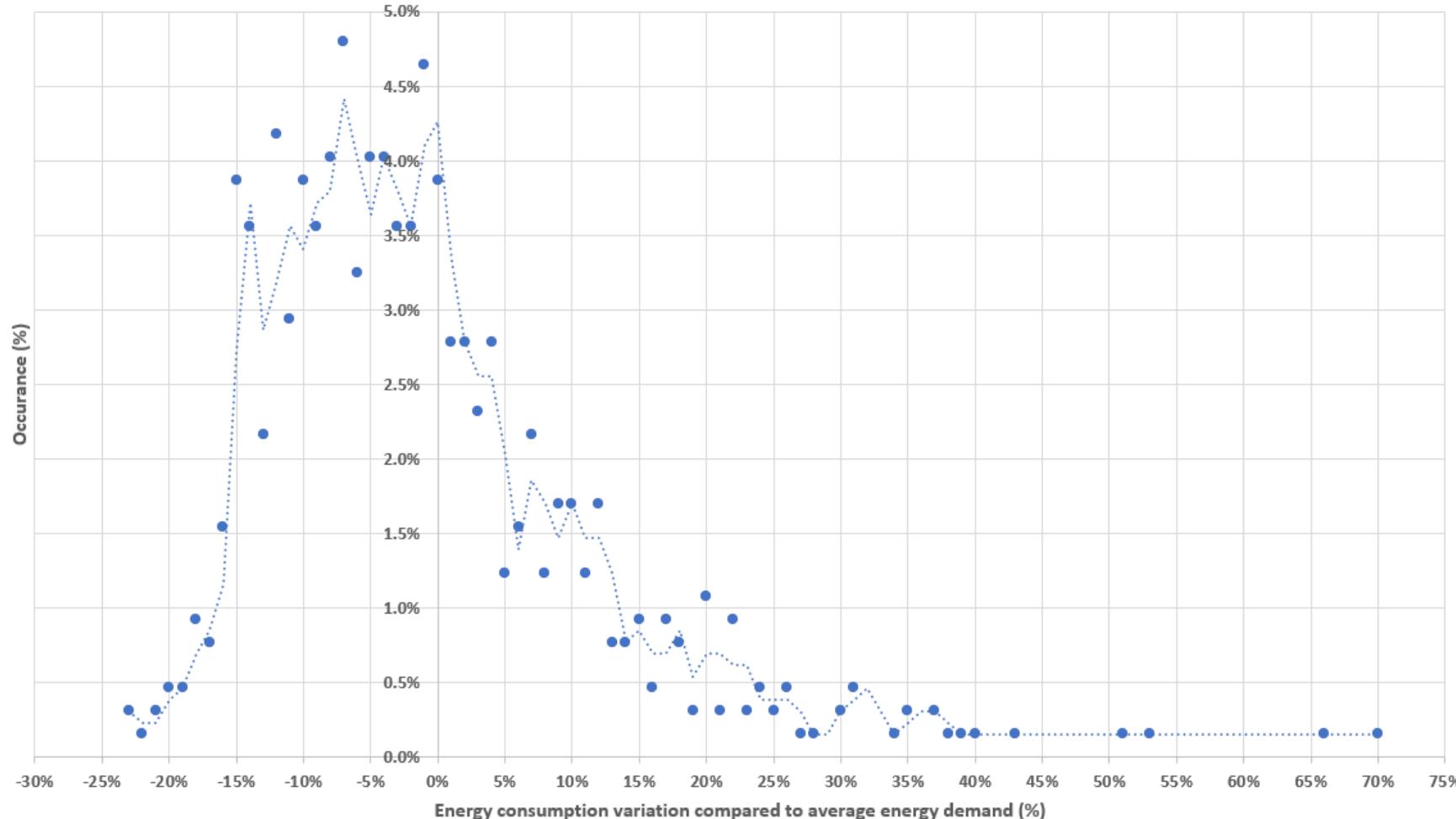
DFDS COTE D'ALBATRE



Speed / Power variability



NEMOSHIP - WP7 - Total Energy consumption variation per trip compared to average demand (%)
Source : DFDS

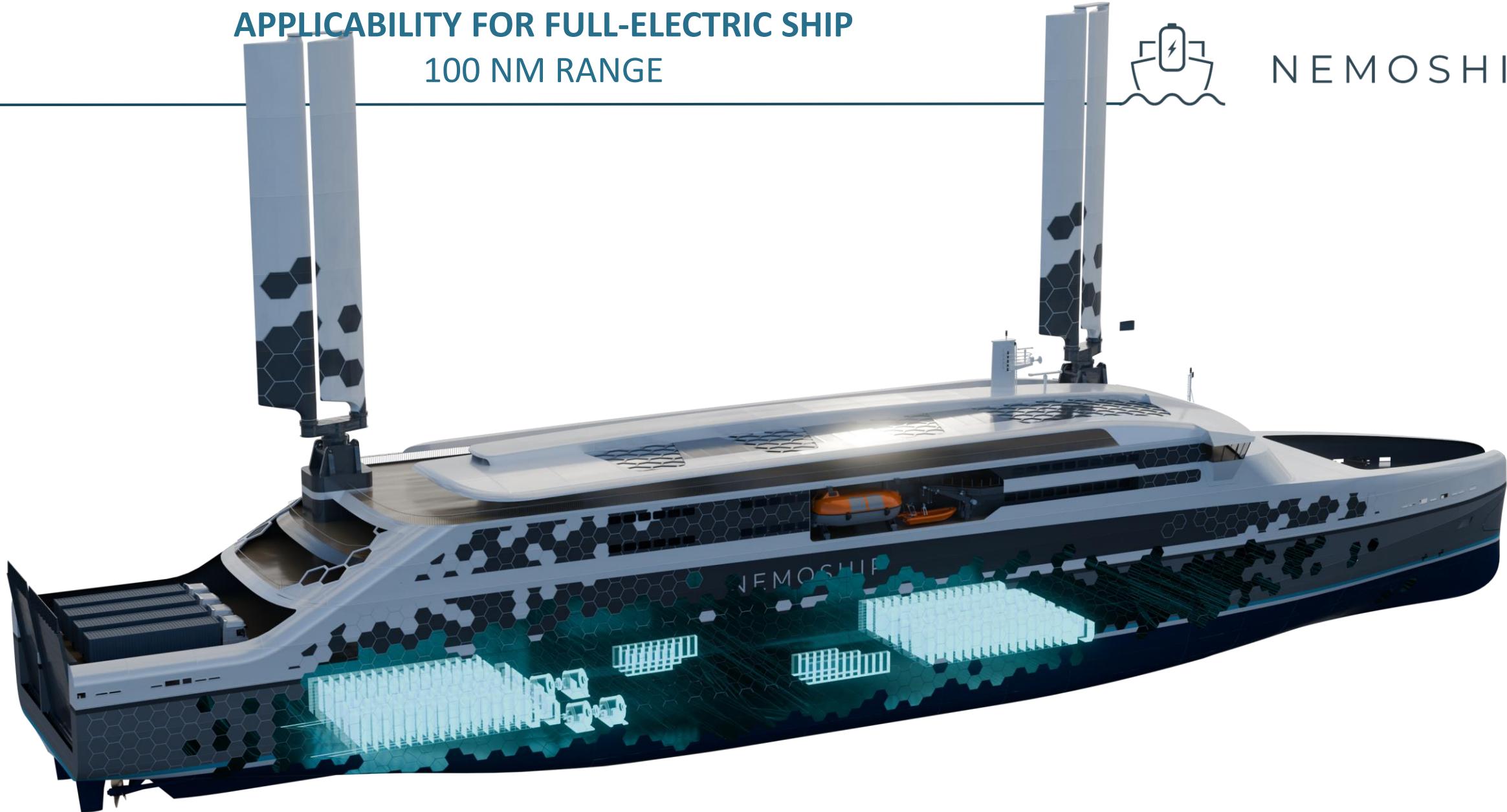


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APPLICABILITY FOR FULL-ELECTRIC SHIP

100 NM RANGE

NEMOSHIP



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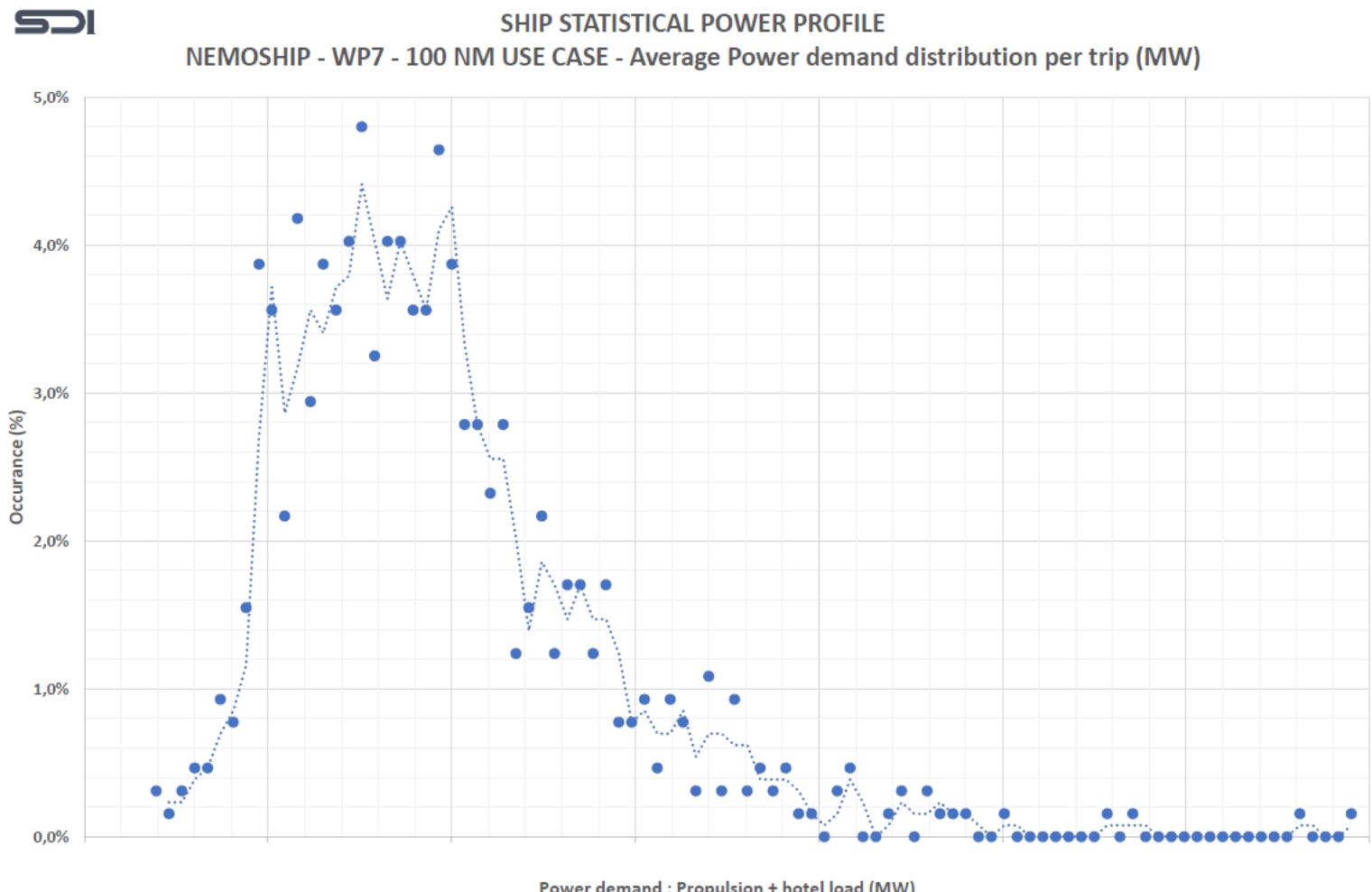
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Power & Energy demand per sea passage

The average power demand **in most severe sailing & weather conditions** has been used to size the BESS.

A maximum **80 % Depth of Discharge (DoD)** has been used for sizing the BESS.





POWER PROFILE

2.5 MW Hotel Load

5.0 MW Average propulsive power

7.5 MW Average power demand

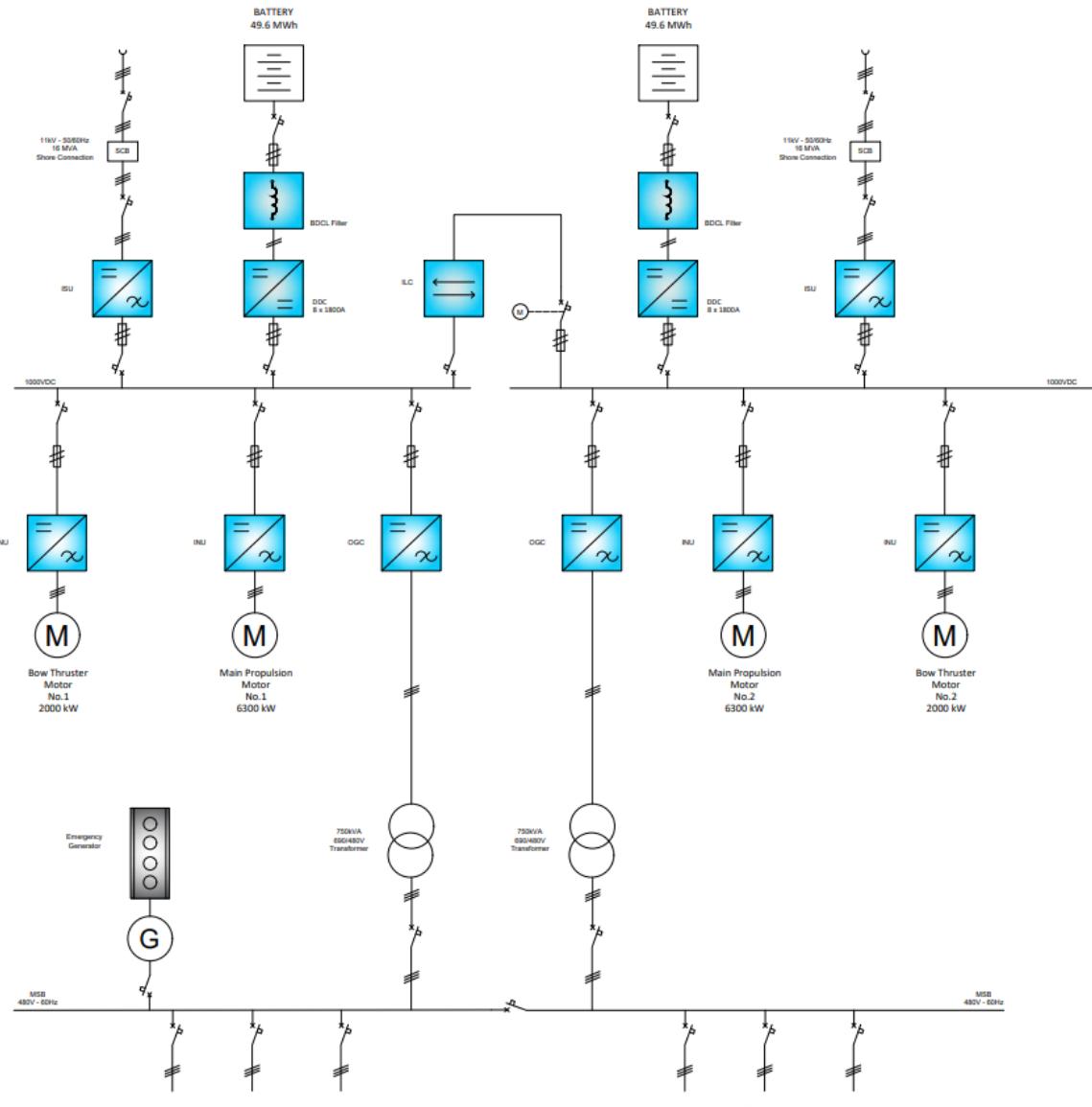
11.0 MW Max power demand

6 h sea passage duration

6 h charging –Power to be defined

2 sea passage per day

260 days of operation per year



© ELKON



POWER PROFILE

2.5 MW Hotel Load

5.0 MW Average propulsive power

7.5 MW Average power demand

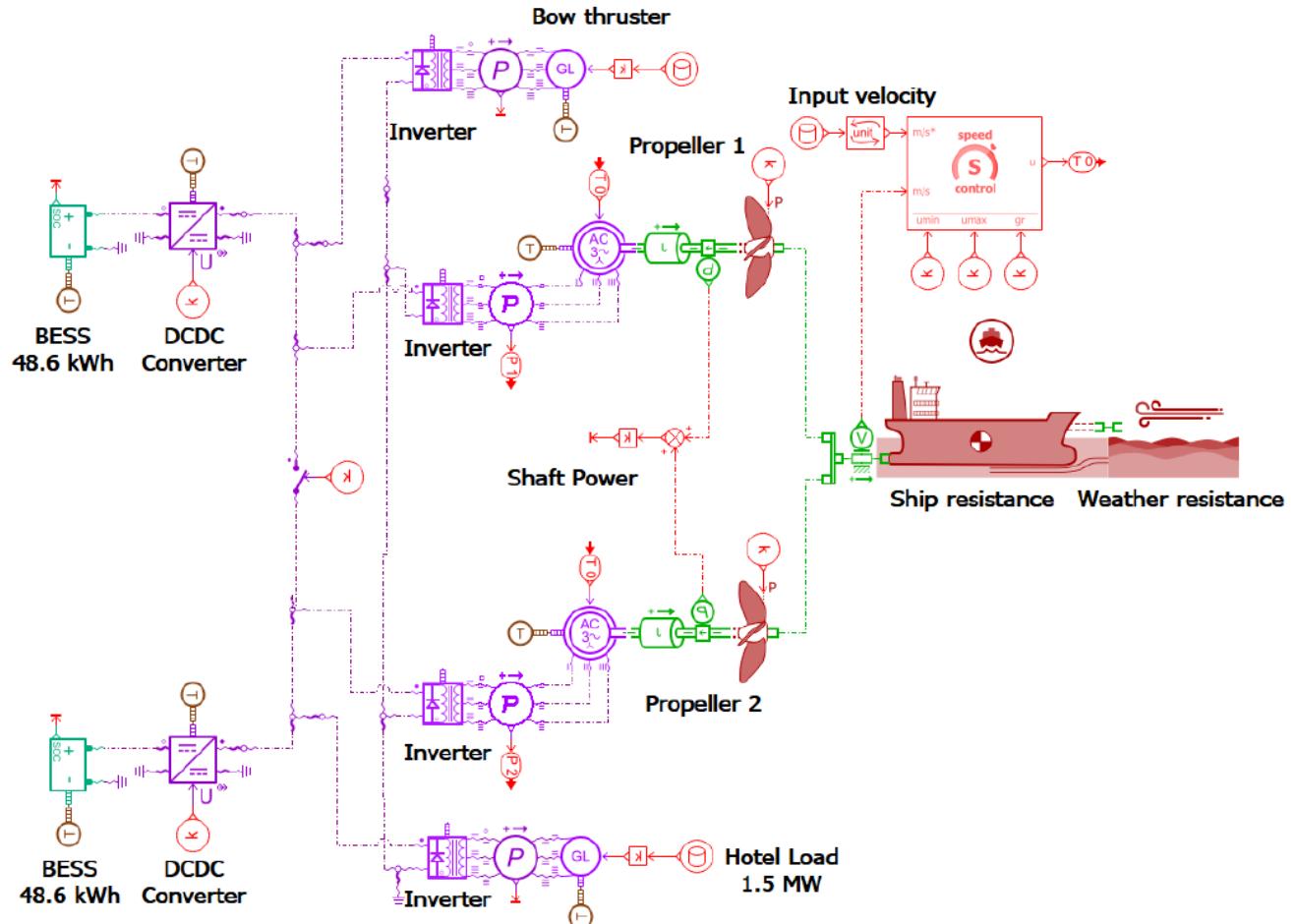
11.0 MW Max power demand

6 h sea passage duration

6 h charging

2 sea passage per day

260 days of operation per year



NEMOSHIP DIGITAL TWIN



NEMOSHIP

Ship energy system simulation with:

NEW MODULAR ELECTRICAL ARCHITECTURE & DIGITAL PLATFORM TO OPTIMISE LARGE BATTERY SYSTEMS ON SHIPS

SIEMENS
DIGITAL INDUSTRIES SOFTWARE
Simcenter Amesim

Select Vessel

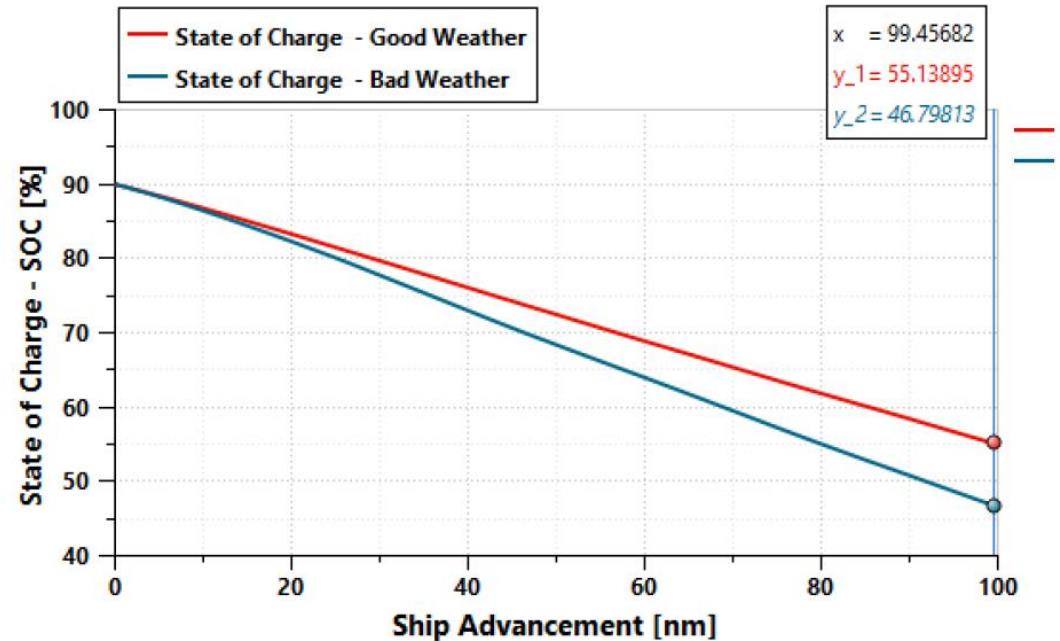
Virtual Use Case 1 - Full Electric

- Le Commandant Charcot
- Normand Drott
- Virtual Use Case 1 - Full Electric

1 Select Route 2 Configure Parameters 3 Simulation Results

Pick one of the predefined travel options below:

| Departure Point | Arrival Point |
|-----------------|---------------|
| Calais | Dover |
| Dunkerque | Dover |
| Montevideo | Buenos Aires |
| Skudeneshavn | Bergen |



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APPLICABILITY FOR FULL-ELECTRIC SHIP: 100 NM RANGE



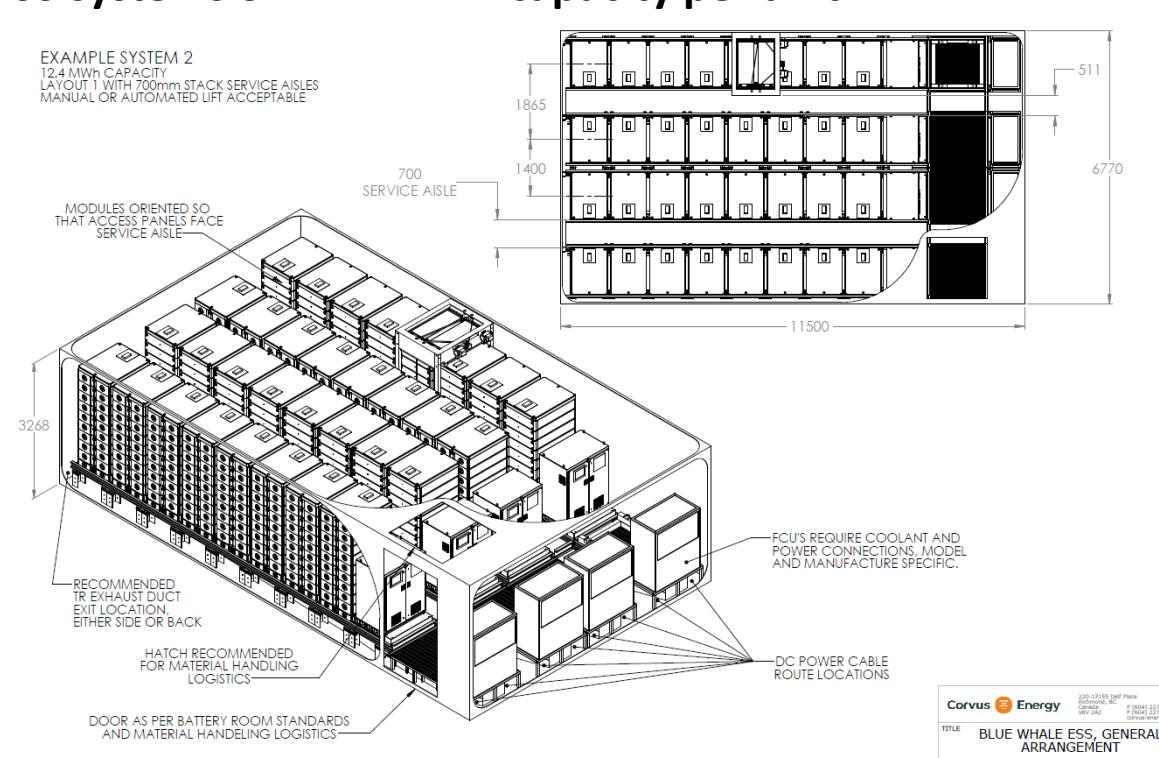
NEMOSHIP

Corvus Energy BESS Capacity

A total BESS capacity of **99.2 MWh** was selected with **Corvus Blue Whale** technology:

- **4 independent BESS systems of 12.4 MWh capacity per unit per Main Fire Zone**
- **At ship scale, a total of 8 independent BESS systems of 12.4 MWh capacity per unit**

Corvus Energy
Powering a clean future



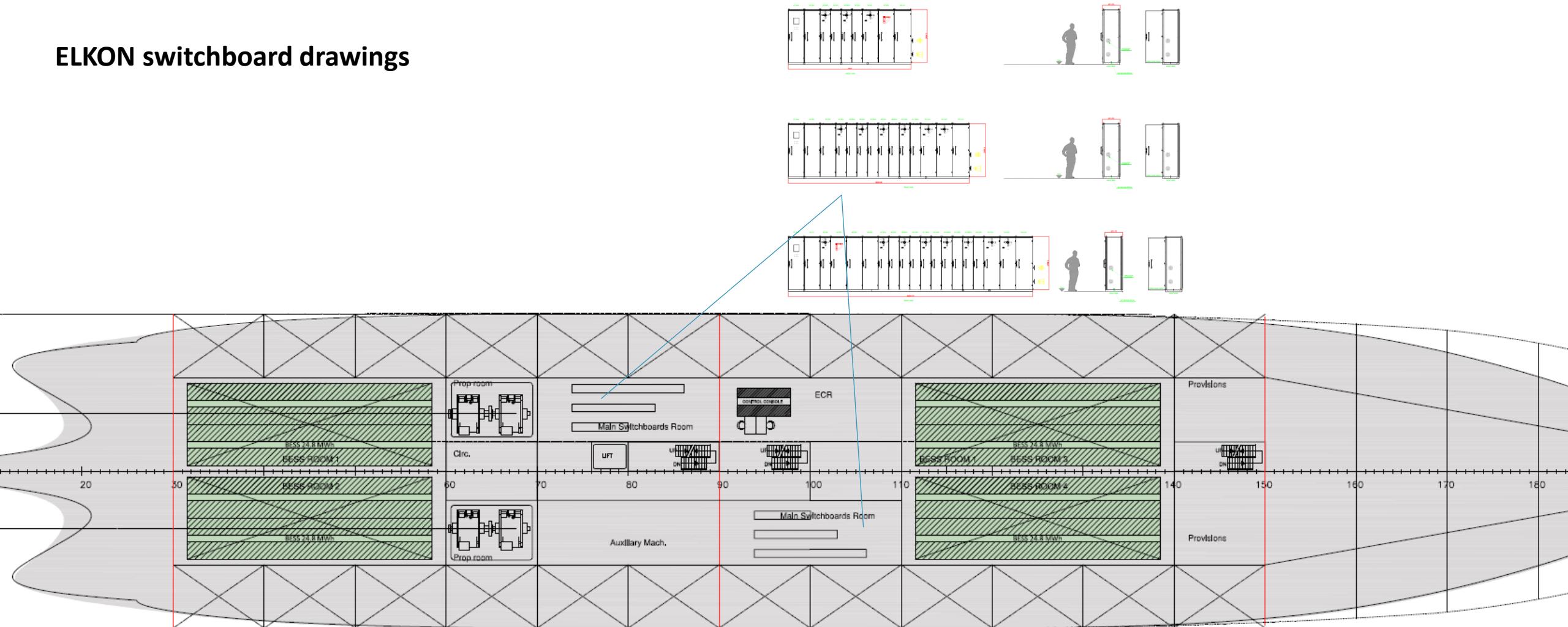
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APPLICABILITY FOR FULL-ELECTRIC SHIP: 100 NM RANGE



NEMOSHIP

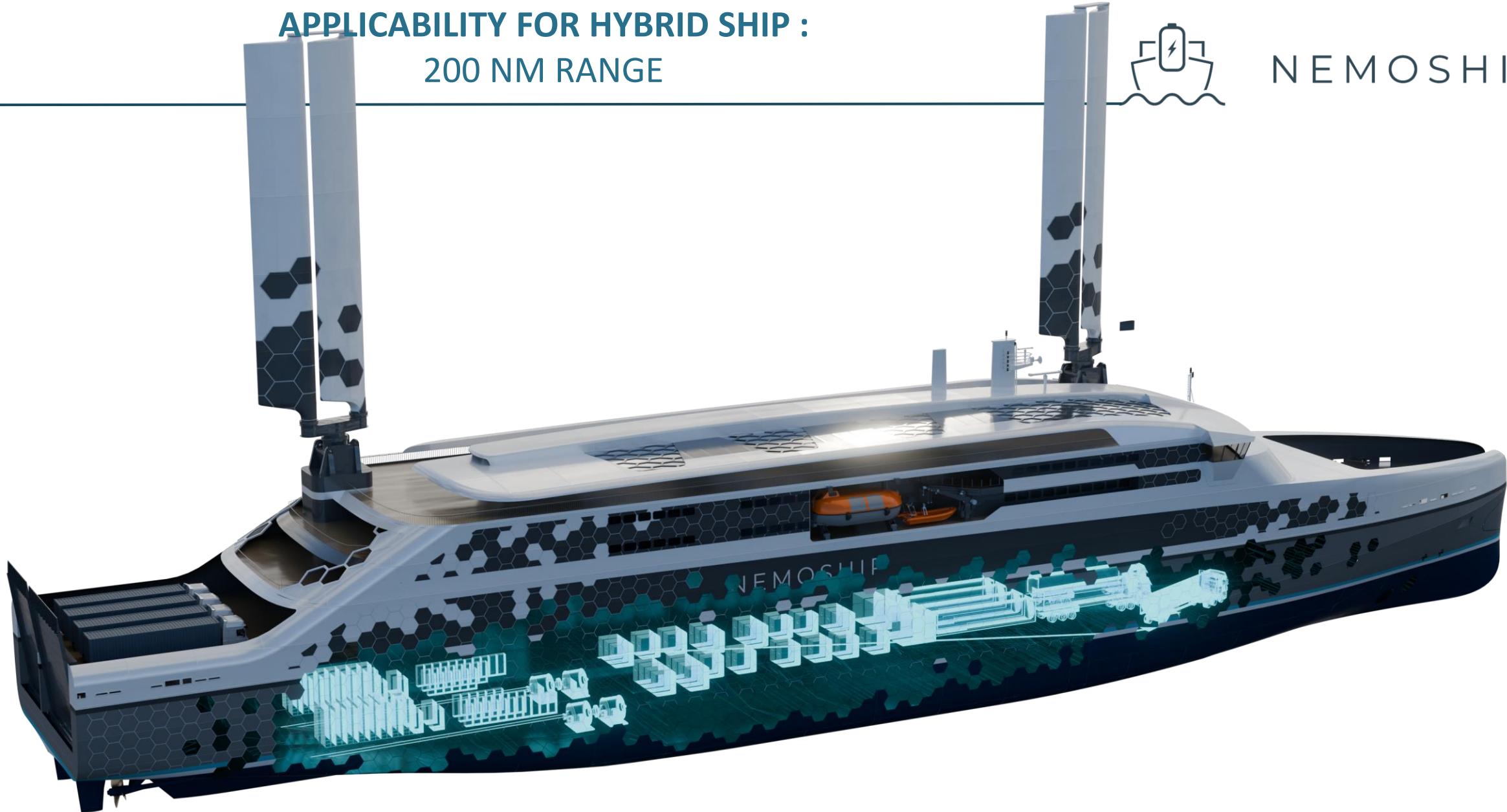
ELKON switchboard drawings



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APPLICABILITY FOR HYBRID SHIP :
200 NM RANGE

NEMOSHIP

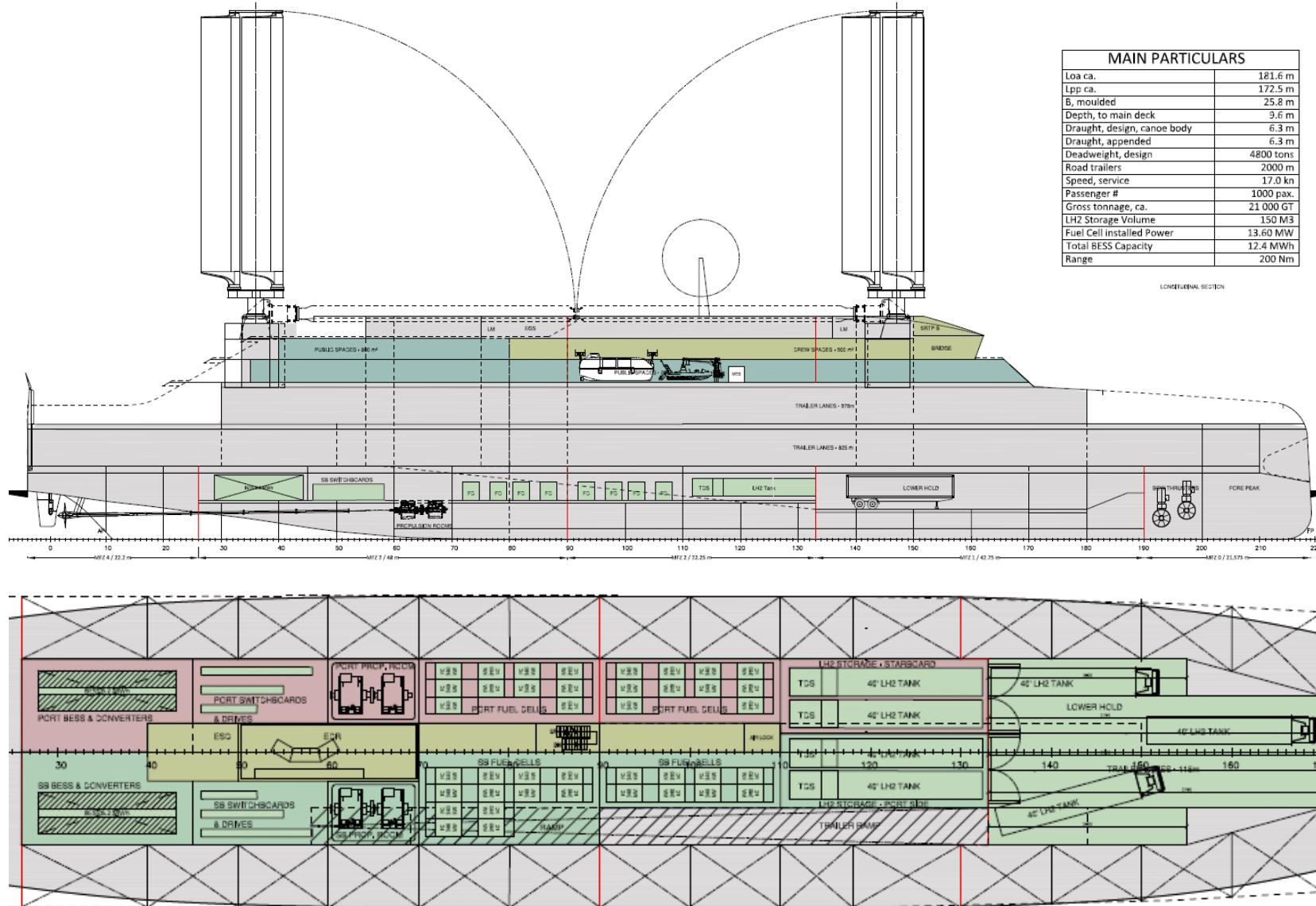


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APPLICABILITY FOR HYBRID SHIP: 200 NM RANGE



NEMOSHIP



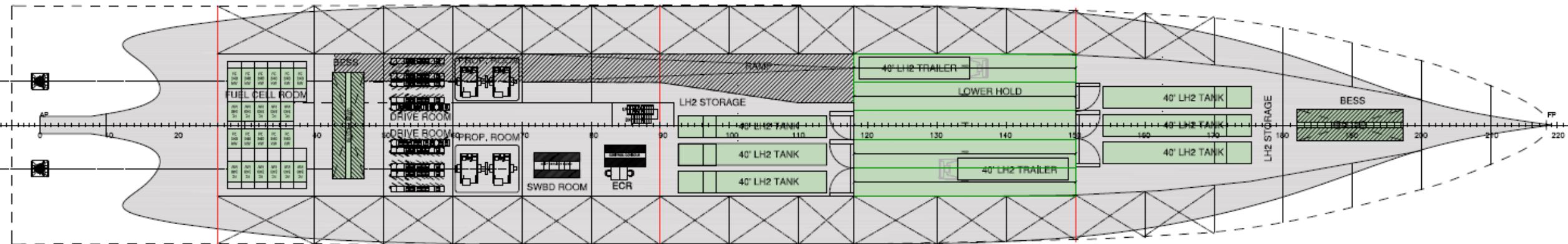
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the European Union

APPLICABILITY FOR HYBRID SHIP: 200 NM RANGE



NEMOSHIP

15 MW Corvus Pelican PEM Fuel Cells | 25 MWh Corvus BESS | Four 45' LH2 containers



Fuel Cell System Specifications

| | |
|--|--|
| Pack Power Size | 340 kW (4 x 85 kW FC module) |
| System Power Range | 340 kW - 10 MW |
| Output Voltage | 400-750 VDC ¹² |
| Pack Weight ($\pm 15\%$) | 3100kg |
| Pack Dimensions, incl. Base and Connections (± 10 mm) | Height: 2320 mm Width: 1427 mm Length: 2159 mm |
| Electrical Connection | Parallel connection 4 FC modules in FC pack |
| Specific H ₂ Consumption | Available upon request |

Corvus  **Energy**
Powering a clean future

APPLICABILITY FOR HYBRID SHIP: > 300 NM RANGE



NEMOSHIP

Main characteristics:

LH2 Storage volume:

300 M3 (8 Tanks)

Fuel cell installed power:

16.3 MW

Total BESS capacity:

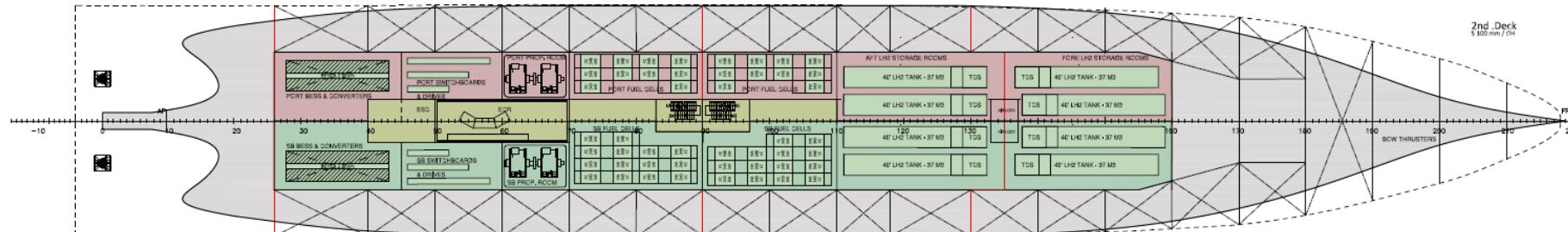
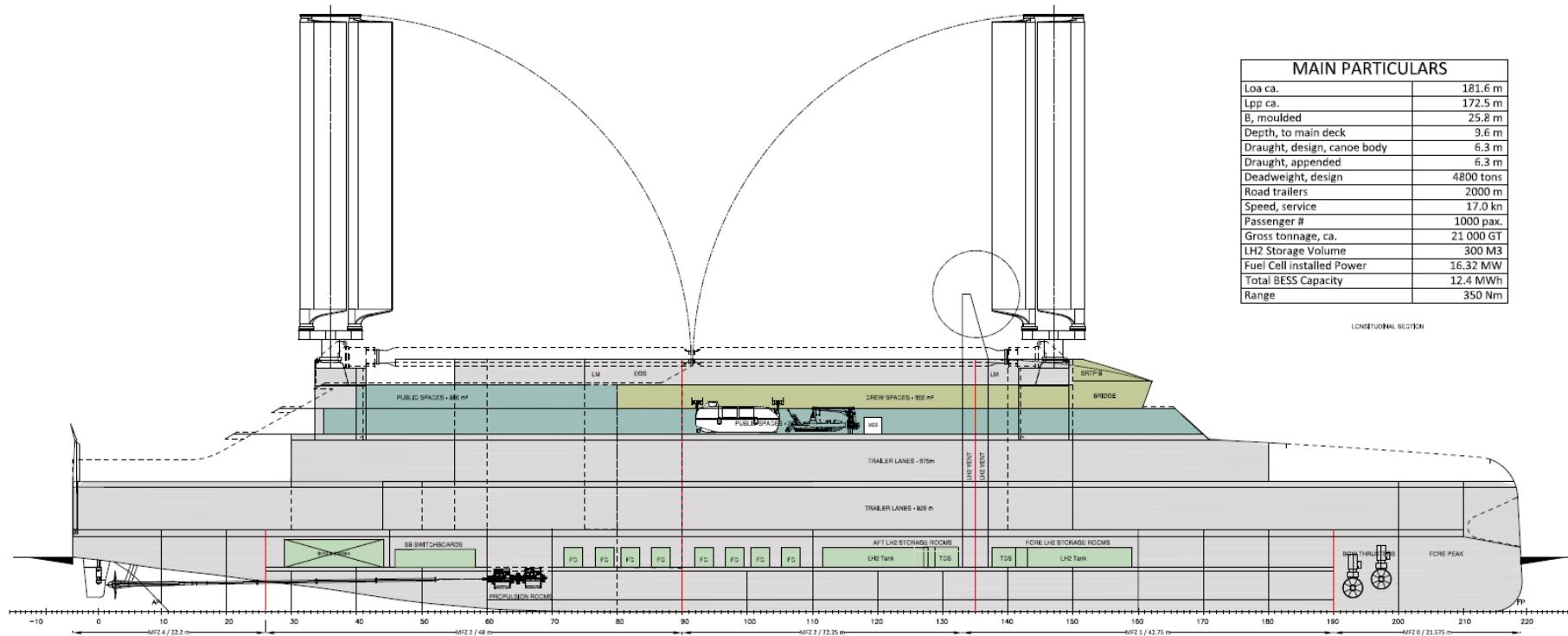
12.4 MWh

Ship range:

> 350 Nm

| MAIN PARTICULARS | |
|-----------------------------|-----------|
| Loa ca. | 181.6 m |
| Lpp ca. | 172.5 m |
| B, moulded | 25.8 m |
| Depth, to main deck | 9.6 m |
| Draught, design, canoe body | 6.3 m |
| Draught, appended | 6.3 m |
| Deadweight, design | 4800 tons |
| Road trailers | 2000 m |
| Speed, service | 17.0 kn |
| Passenger # | 1000 pax. |
| Gross tonnage, ca. | 21 000 GT |
| LH2 Storage Volume | 300 M3 |
| Fuel Cell installed Power | 16.32 MW |
| Total BESS Capacity | 12.4 MWh |
| Range | 350 Nm |

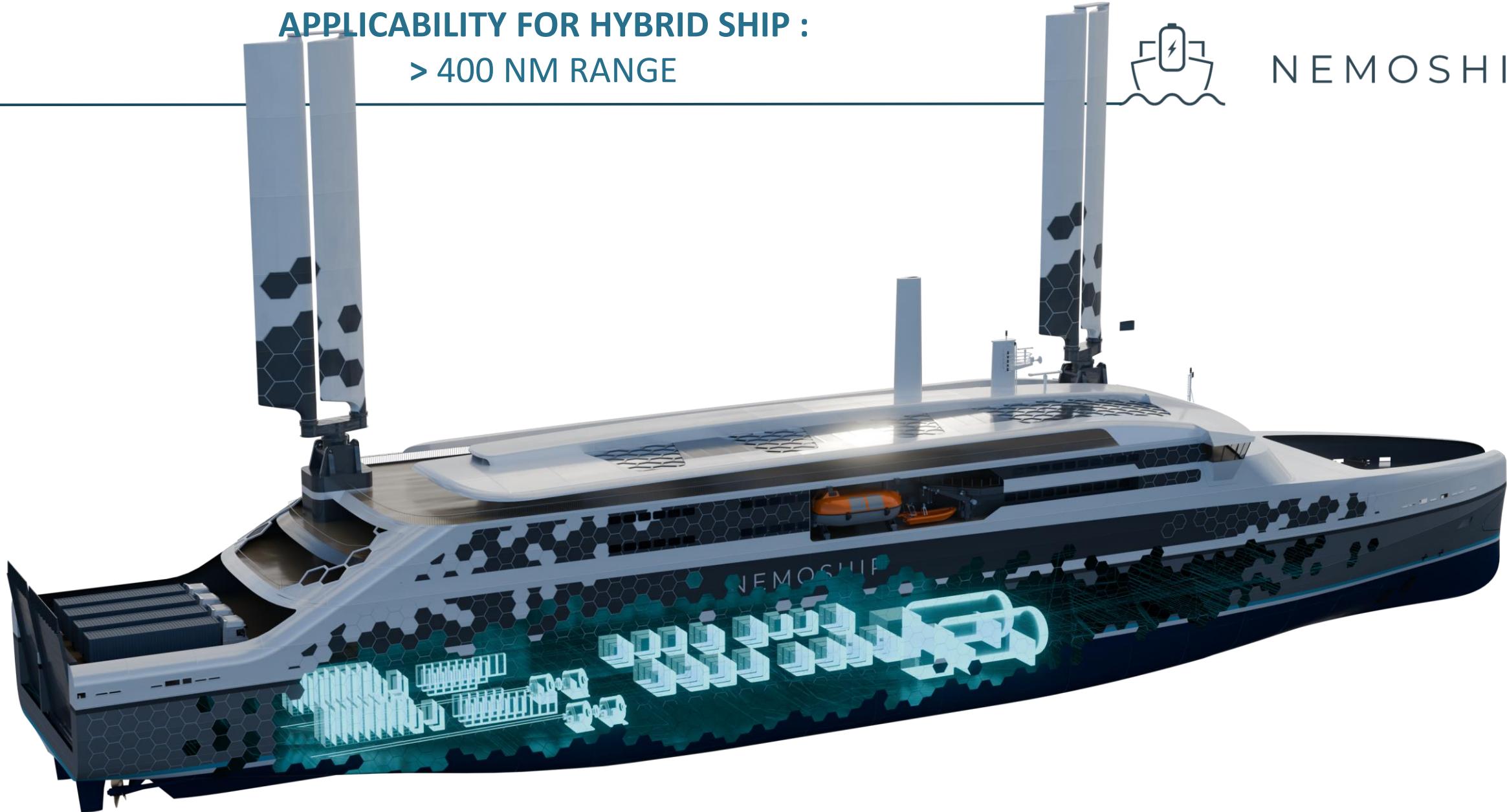
LONGITUDINAL SECTION



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APPLICABILITY FOR HYBRID SHIP :
> 400 NM RANGE

NEMOSHIP



APPLICABILITY FOR HYBRID SHIP : > 400 NM RANGE



NEMOSHIP

Main characteristics :

LH2 Storage volume :

330 M3 (2 Tanks)

Fuel cell installed power:

16.3 MW

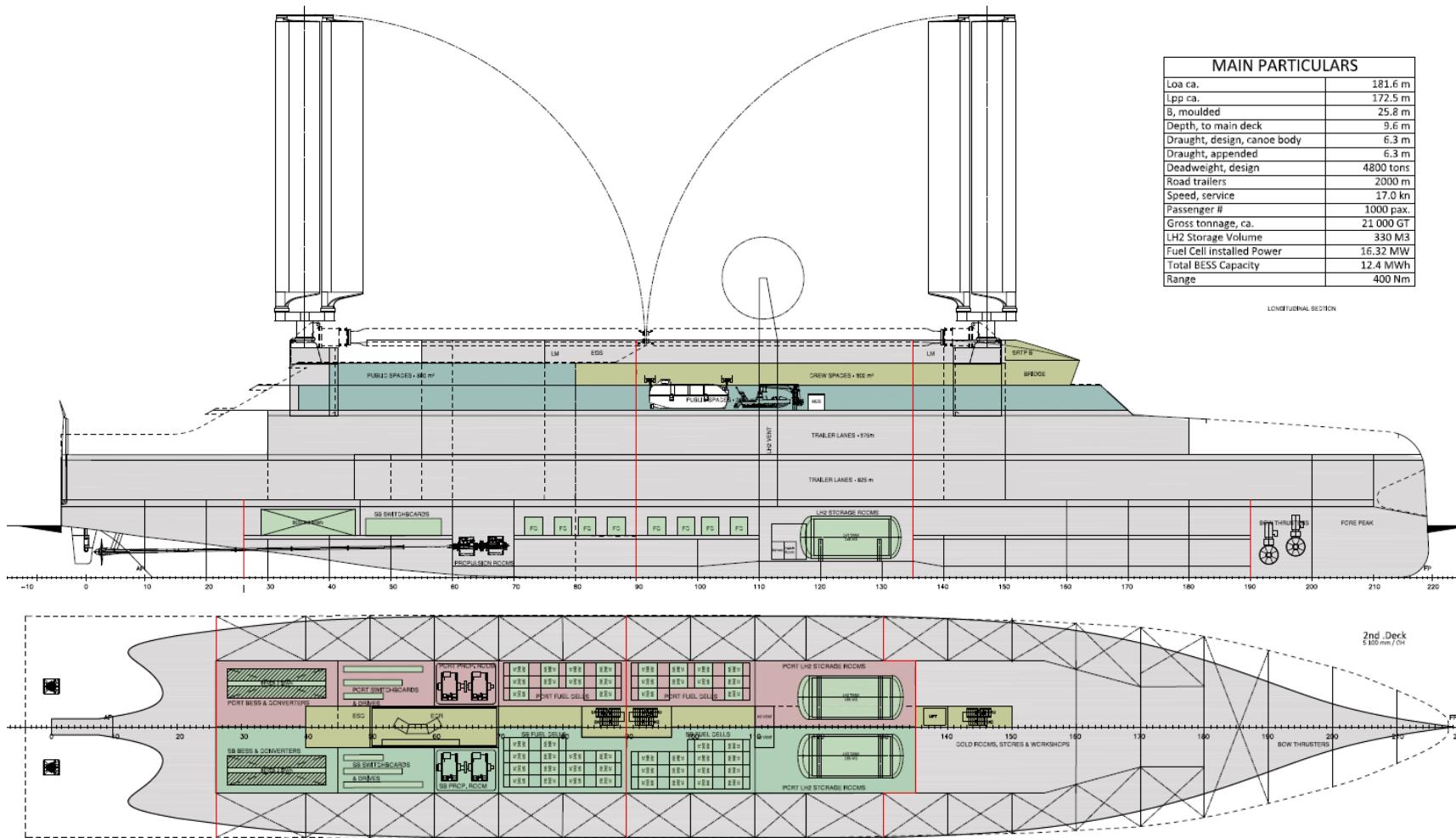
Total BESS capacity:

12.4 Mwh

Ship range:

> 400 Nm

| MAIN PARTICULARS | |
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| Loa ca. | 181.6 m |
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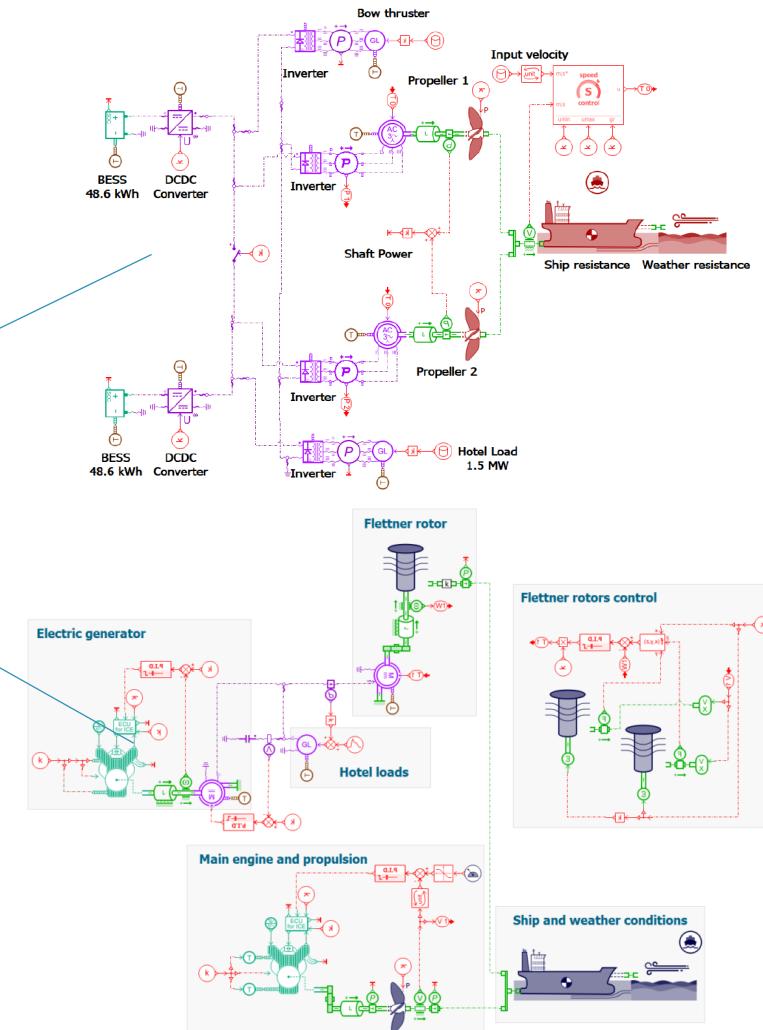
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HYBRIDISATION BETWEEN BESS AND WIND ASSISTED PROPULSION

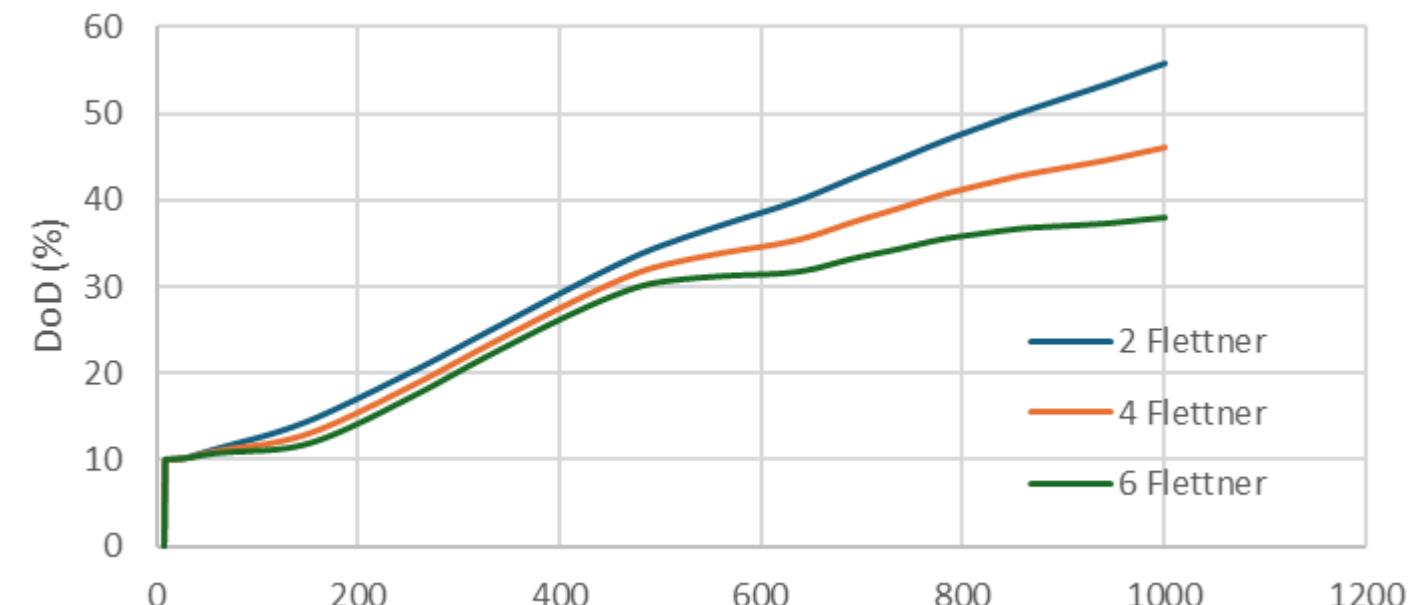


NEMOSHIP

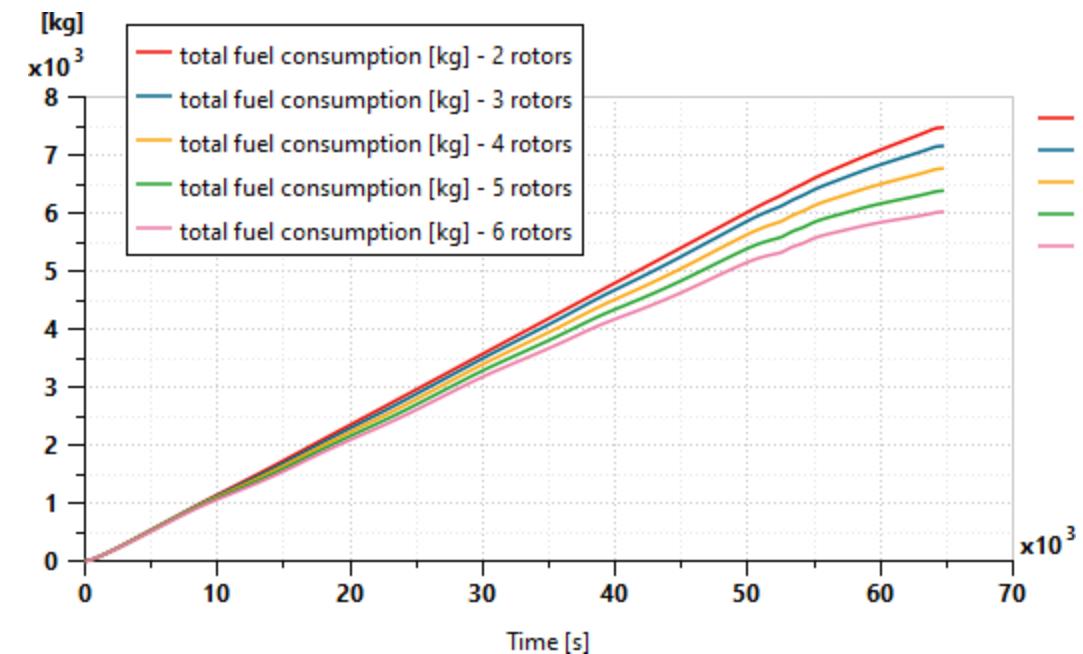
Wind propulsion
system
&
Battery system
modeling in
Simcenter Amesim
for simulations in
the time domain



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Average DoD vs. number of Flettner rotors Bad Weather – UC1



Hydrogen consumption vs. rotor number – 03/01/2024 weather



Ro-Pax ships

CO2 Emissions

versus

Average Voyage Distance

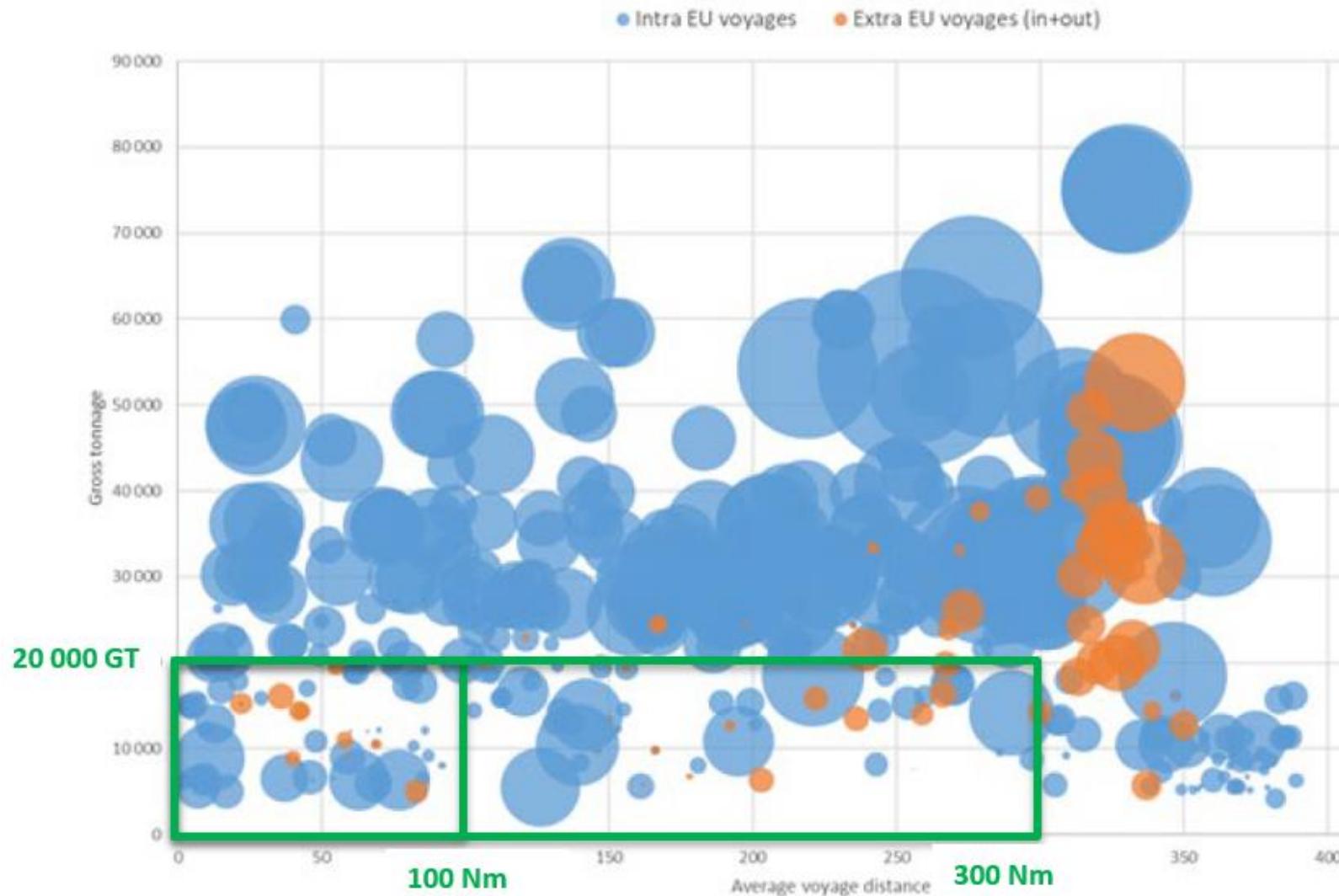


Figure 3 – CO2 Emissions of Ro-Pax ships in EU (2019) as a function of average voyage distance in Nautical Miles - Source: 2020 Annual Report on CO2 Emissions from Maritime Transport (European Commission) [1]



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NEMOSHIP

APPLICABILITY TO FULL ELECTRIC USE CASES

Mert Can Çelik, Elkon



- Definition and assessment of **modular DC electrical architectures** for hybrid and fully electric ships
- Development of **high-fidelity power electronics converter models** by VUB
- Assessment of **heterogeneous battery hybridization (HE/HP)** for scalability and modularity by CEA
- System-level evaluation using:
 - Two **Virtual Use Cases** (100 nm full-electric, 300 nm hybrid-electric)
 - Two **demonstration vessels** (Normand Drott, Le Commandant Charcot)
- Integration of **large-scale BESS and hybrid energy sources** (batteries + fuel cells)
- Analysis of **operational modes, energy flows, redundancy, and protection concepts**
- Comparative **AC vs DC architecture assessment** under realistic operational profiles

DEFINITION OF USE CASES



NEMOSHIP

- Two **Virtual Use Cases**:
 - 100 nm full-electric
 - 300 nm hybrid-electric
- Two **demonstration vessels**:
 - Normand Drott (tug/supply vessel)
 - Le Commandant Charcot (icebreaking cruise vessel)



Normand Drott



Le Commandant Charcot



100 nm full-electric

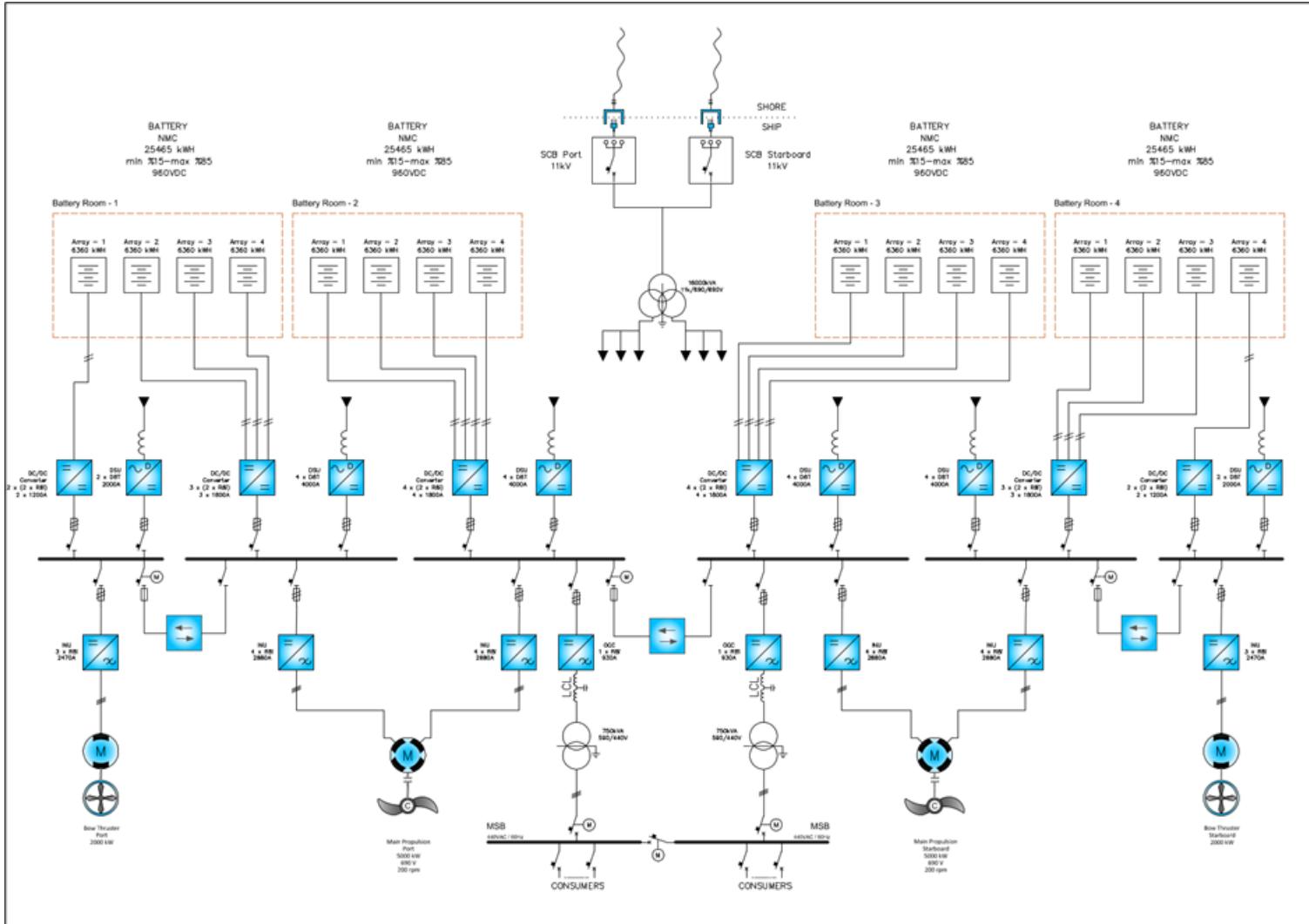


300 nm hybrid-electric

VIRTUAL USE CASE 1 (FULL-ELECTRIC, 100 NM)



NEMOSHIP



POWER ELECTRONIC MODULES – SIZING TOOL



NEMOSHIP

| Optimal grid control output parameters | | |
|---|------|-------|
| Output grid AC voltage U_{ac} (line-to-line) | 590 | V RMS |
| Output grid frequency f_{grid} | 60 | Hz |
| Load power factor $\cos \varphi$ | 0,86 | - |
| Grid load: inductive = -1, capacitive = 1 | -1 | - |
| Compensated load current THD | 0 | % |
| Apparent output power S_N to grid | 750 | kVA |
| Load current unbalance | 0 | % |
| DC link voltage | 1000 | V DC |
| Surrounding air temperature | 45 | °C |
| Incoming internal coolant temperature | 40 | °C |
| Components with a maximum operating temperature of 55 °C | No | - |
| Required short-circuit current (max. 5 sec for air cooled and liquid cooled R7i, 2 sec for liquid cooled R8i) | 0 | A RMS |
| | | |
| Calculations | | |
| Phase (load) current = $S_N / (\sqrt{3} * U_{ac})$ | 734 | A RMS |

| | Type | Frame | Nominal ISU current | DC link voltage needed | Available short-circuit current | Available short-circuit current with 5% additional inductance | Additional DC boost | De-rated / required | Conclusion | Comments |
|----------|----------------------|---------|---------------------|------------------------|---------------------------------|---|---------------------|---------------------|------------|-----------------------|
| 690 V LC | ACS880-207LC-0620A-7 | 1 x R8i | 620 | 1000 | 651 | 749 | | 79% | Not OK | Load current too high |
| | ACS880-207LC-0700A-7 | 1 x R8i | 700 | 1000 | 735 | 893 | | 89% | Not OK | Load current too high |
| | ACS880-207LC-0770A-7 | 1 x R8i | 770 | 1000 | 809 | 1019 | | 98% | Not OK | Load current too high |
| | ACS880-207LC-0930A-7 | 2 x R8i | 930 | 1000 | 977 | 1302 | | 118% | OK | |
| | ACS880-207LC-1090A-7 | 2 x R8i | 1090 | 1000 | 1145 | 1526 | | 138% | OK | |



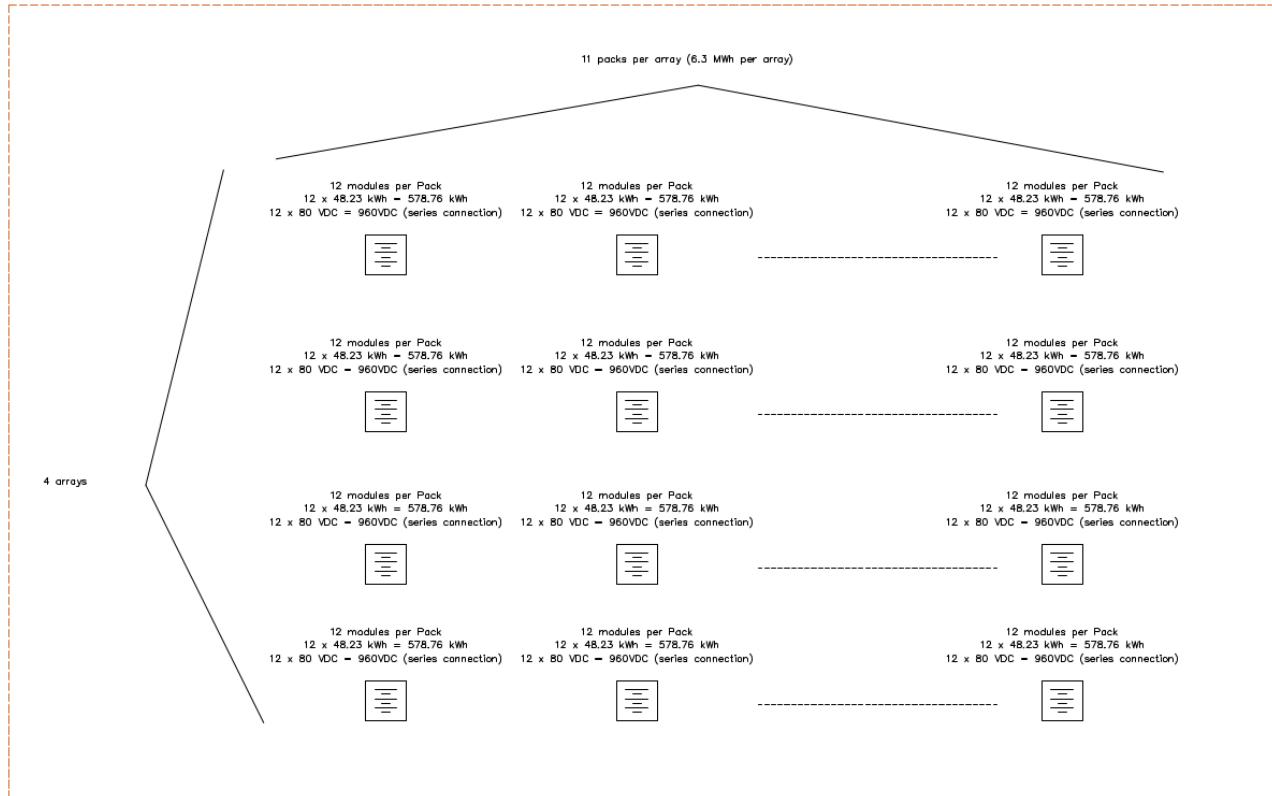
Co-funded by
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VIRTUAL USE CASE 1 (FULL-ELECTRIC, 100 NM)



NEMOSHIP

Battery Room - 1



Technical Specifications | Corvus Blue Whale

Performance Specifications

| | |
|--|------------------------|
| C-Rate - Peak (Discharge / Charge) | 1C / 1C for 20 minutes |
| C-Rate - Continuous (Discharge / Charge) | 0.7C / 0.7C |

System Specifications

| | |
|---------------------------------------|-------------------------------|
| Single Module Size / Increments | 44.35 kWh / 80 VDC |
| Single Pack Range | 310-4967 kWh / 560 - 1120 VDC |
| Max Gravimetric Density - Room | 105 Wh/kg 9.6 kg/kWh |
| Max Volumetric Density - Room | 58 Wh/l |

Example Pack - 6 Strings (14 modules/string)

| | |
|------------|--|
| Energy | 3726 kWh |
| Voltage | Max: 1226 VDC Nom: 1109 VDC Min: 840 VDC |
| Dimensions | Height: 2755 mm Width: 1390 mm Length: 10 047 mm |
| Weight | 37 296 kg |

Example System - 4 Packs of 6 Strings (14 modules/string)

| | |
|------------|--|
| Energy | 14 902 kWh |
| Voltage | Max: 1226 VDC Nom: 1109 VDC Min: 840 VDC |
| Dimensions | Height: 2755 mm Width: 5560 mm Length: 10 047 mm |
| Weight | 149 184 kg |

Safety Specifications

| | |
|----------------------------------|--|
| Thermal Runaway Anti-Propagation | Passive cell-level thermal runaway isolation with exhaust gas system |
| Fire Suppression | Per SOLAS, class and Corvus recommendation |
| Disconnect Circuit | Hardware-based fail-safe for over-temperature and over-voltage |
| Short Circuit Protection | Fuses included on the module and string level |
| Emergency Stop Circuit | Hard-wired |
| Ground Fault Detection | Integrated |
| Disconnect Switchgear Rating | Full load |

General Specifications

| | |
|----------------------------|--------------------------------------|
| Class Compliance [Pending] | Lloyds Register, Bureau Veritas, ABS |
| Type Approval | DNV, RINA |
| Ingress Protection | System: IP44 |
| Cooling | Forced air |
| Vibration and Shock | UNT38.3, DNV-CG-0339, IEC 60068-2-6 |
| EMC | IEC 61000-4, CISPR16-2-1 |

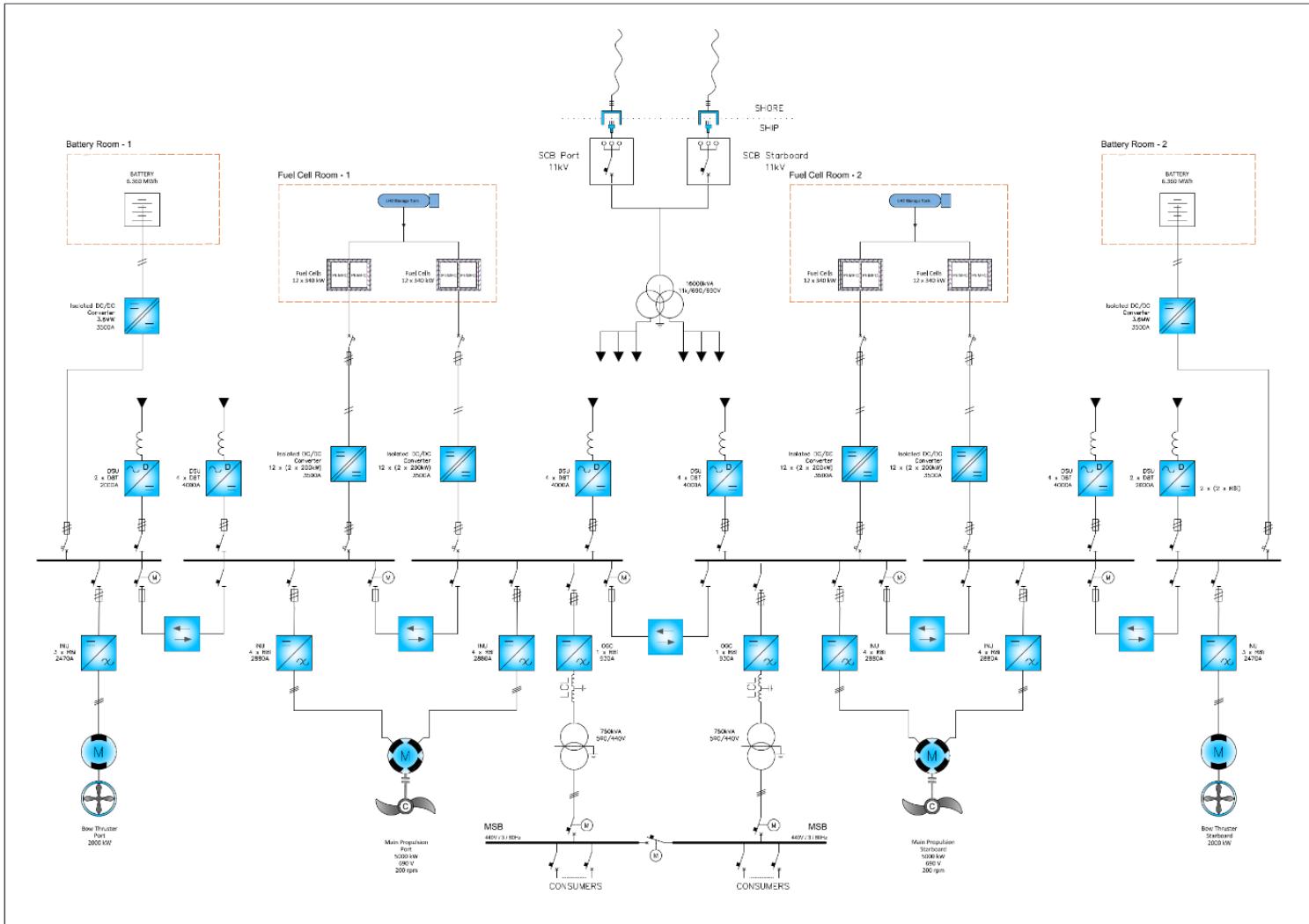


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VIRTUAL USE CASE 2 (HYBRID-ELECTRIC, 300 NM)



NEMOSHIP

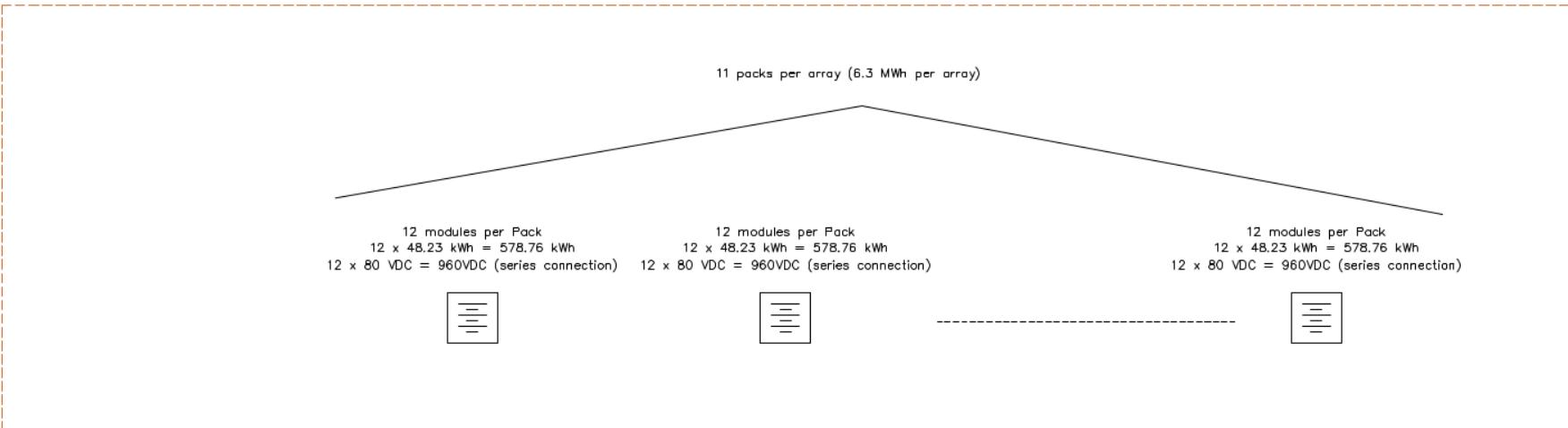


VIRTUAL USE CASE 2 (HYBRID-ELECTRIC, 300 NM)



NEMOSHIP

Battery Room - 1

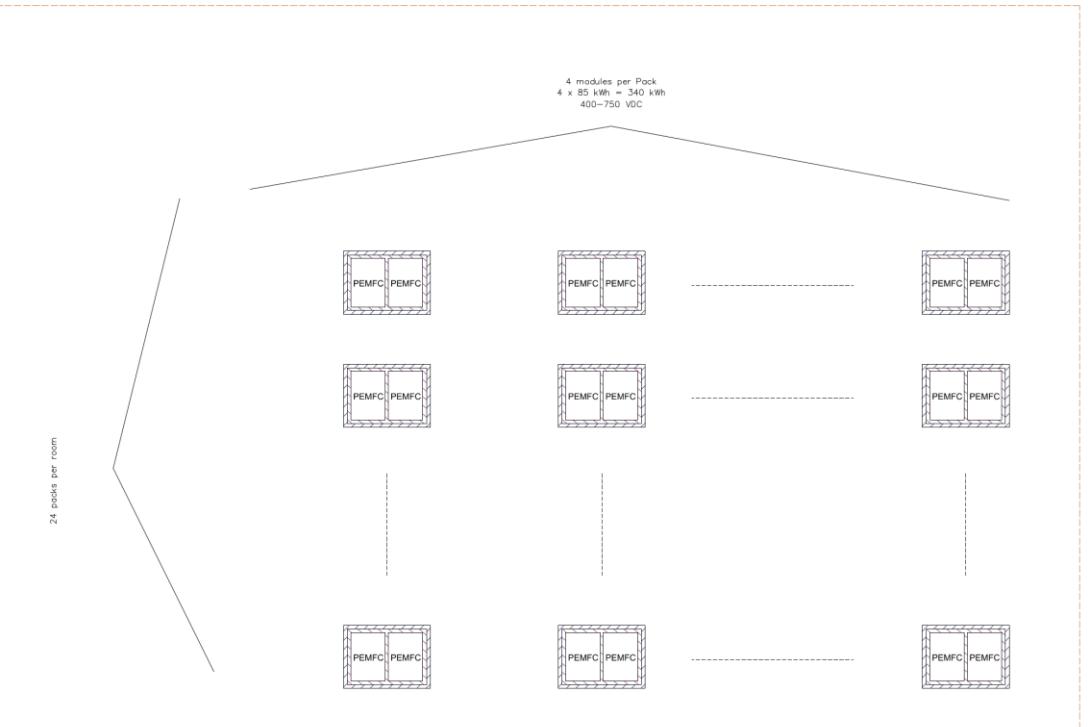


VIRTUAL USE CASE 2 (HYBRID-ELECTRIC, 300 NM)



NEMOSHIP

Fuel Cell Room - 1



Fuel Cell System Specifications

| | |
|--|--|
| Pack Power Size | 340 kW (4 x 85 kW FC module) |
| System Power Range | 340 kW - 10 MW |
| Output Voltage | 400-750 VDC ¹² |
| Pack Weight (±15%) | 3100kg |
| Pack Dimensions, incl. Base and Connections (±10 mm) | Height: 2320 mm Width: 1427 mm Length: 2159 mm |
| Electrical Connection | Parallel connection 4 FC modules in FC pack |
| Specific H ₂ Consumption | Available upon request |

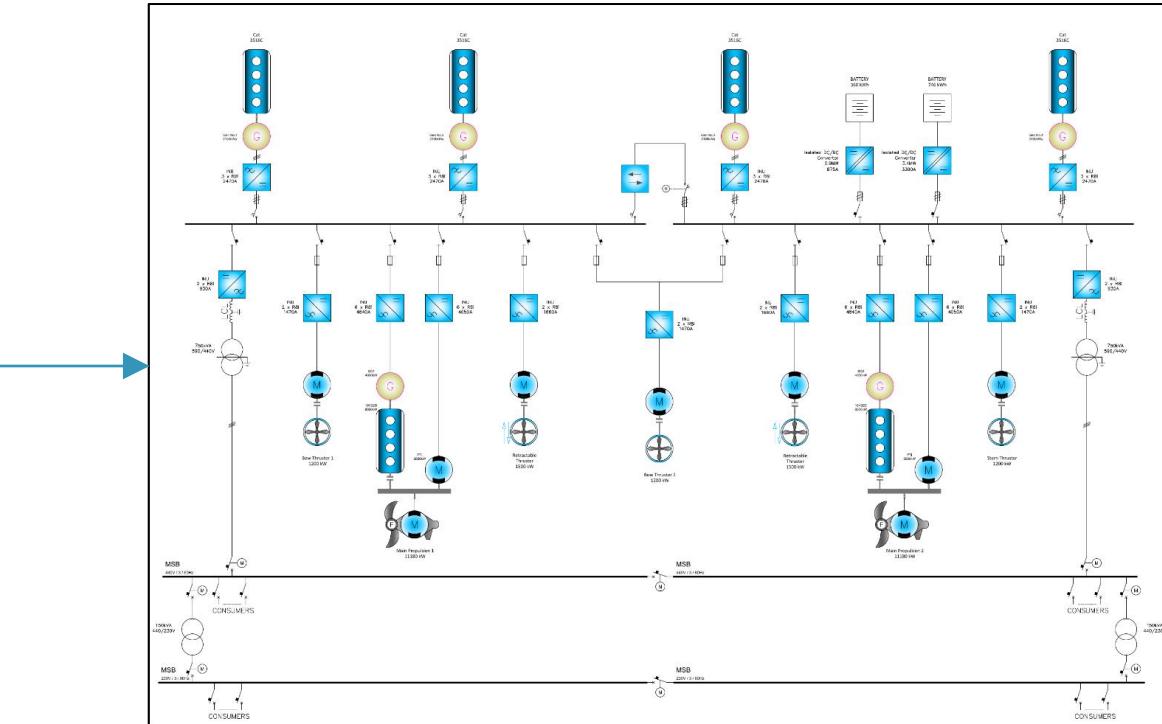
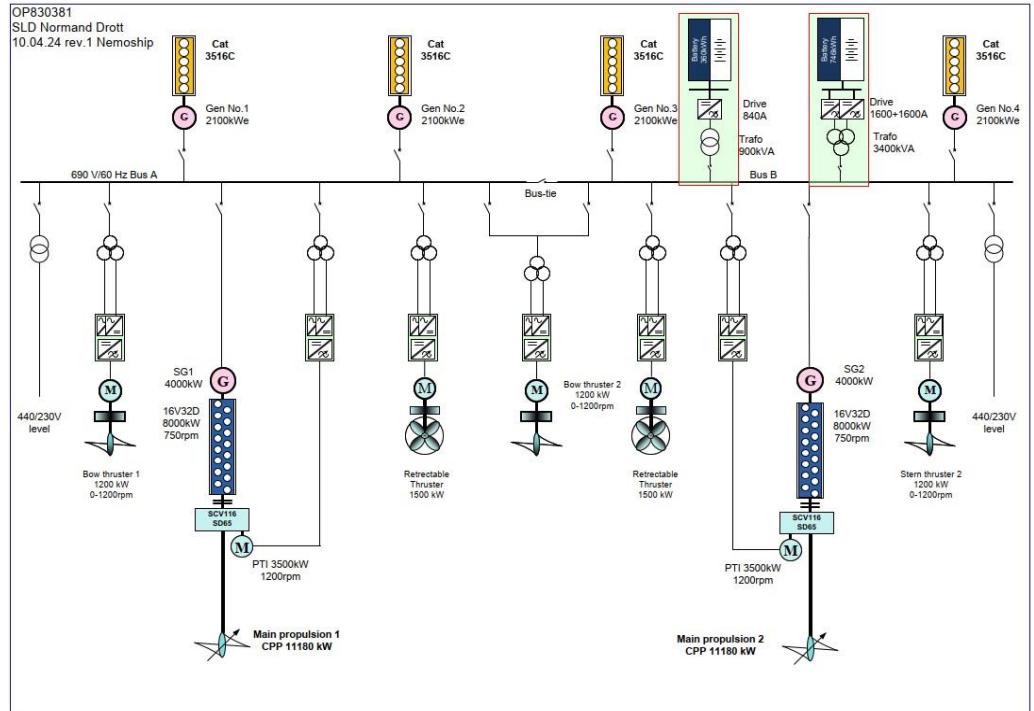


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NORMAND DROTT – ADAPTATION TO DC NETWORK



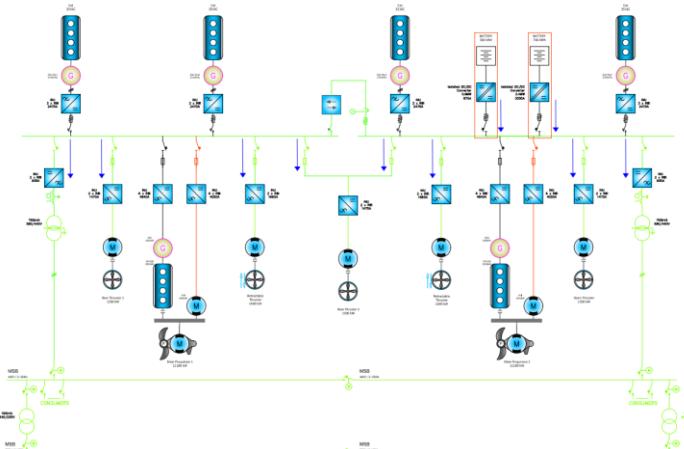
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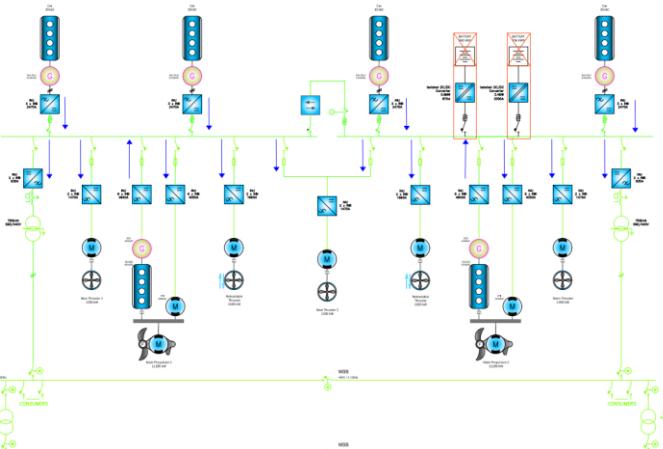
NORMAND DROTT – OPERATIONAL MODES



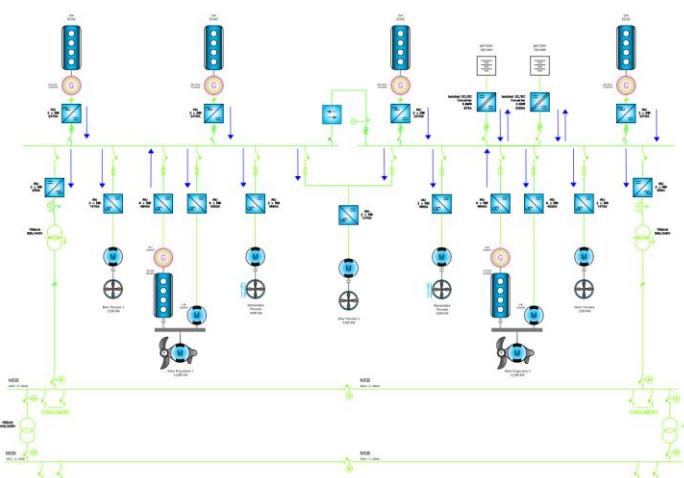
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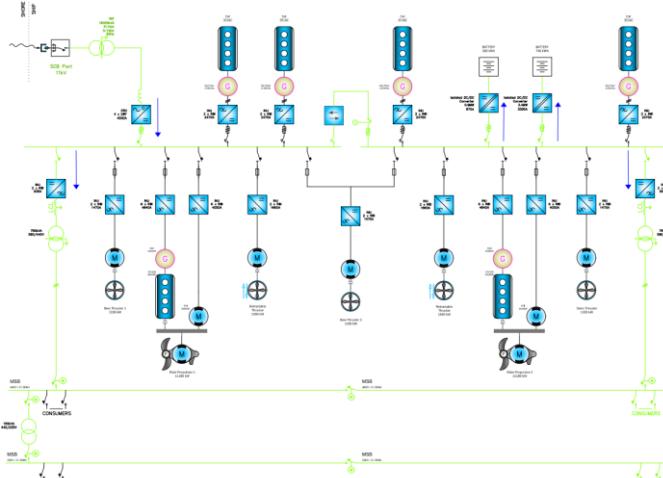
Battery Mode



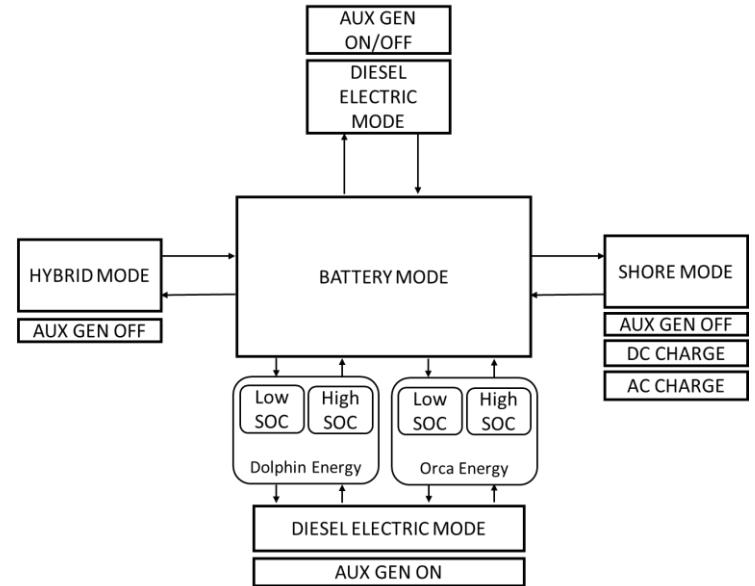
Diesel Electric Mode



Hybrid Mode



Shore Mode



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- Use of defined DC architectures as the baseline for future project analyses
- Application to full-electric and hybrid-electric vessel use cases
- Assessment of battery sizing, modular ESS, and DC charging concepts
- Alignment with energy management (WP4) and digital models (WP2)
- Preparation for semi-virtual and P-HiL validation activities



Q&A FOR:

- **Applicability to full electric use cases / Thibaut Tincelin, SDI and Mert Can Çelik, Elkon**



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CLOSING

KEEP IN TOUCH



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